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Environmental Support to Amphibious Craft, Patrol Boats, and Coastal Ships: An Annotated Bibliography

Charles M. Bachmann
Robert A. Fusina

Coastal and Ocean Sensing Branch
Remote Sensing Division

C. Reid Nichols

Marine Information Resources Corporation
Ellicott City, Maryland

Jack McDermid

Acoustic Simulation, Measurements and Tactics Branch
Acoustics Division

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*Marine Information Resources Corporation, Ellicott City, MD

14. ABSTRACT
This annotated bibliography is a selection of citations to books, articles, documents, and databases highlighting environmental conditions that impact the safety and performance of amphibious craft, patrol boats, and ships designed for coastal operations. Each citation is followed by a brief summary and evaluation of the source (i.e., the annotation). Most annotations will define the scope of the source, list significant cross references, and identify the relevant environmental conditions. There is no attempt to provide actual hypotheses, data, or graphics, especially concerning cited articles published in refereed journals. The purpose of the annotation is to inform the reader of the relevance, accuracy, and quality of the sources cited. Relevance relates to the citation's presentation of environmental conditions such as ambient air temperature, sea surface conditions (wave height, wave period, wave direction, spectral distribution), tidal regime, currents, wind conditions (direction, speed, and gusts), terrain (beach gradients and obstacles), and surf zone parameters (breaker type, surf zone width, longshore currents).

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Environmental Support to Amphibious Craft, Patrol Boats, and Coastal Ships: An Annotated Bibliography

Prepared by:
Charles M. Bachmann,[1] C. Reid Nichols,[2] Robert A. Fusina,[1] and Jack McDermid,[3]

[1]Remote Sensing Division,
Naval Research Laboratory,
Washington, D.C.

[2]Marine Information Resources Corporation
Ellicott City, MD

[3]Acoustics Division,
Naval Research Laboratory,
Stennis Space Center, MS

Prepared for:
Naval Surface Warfare Center-Carderock Division
Carderock, MD

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I. INTRODUCTION

This annotated bibliography is a selection of citations to books, articles, documents, and databases highlighting environmental conditions that impact the safety and performance of amphibious craft, patrol boats, and ships designed for coastal operations. Each citation is followed by a brief summary and evaluation of the source, the annotation. Most annotations will define the scope of the source, list significant cross references, and identify the relevant environmental conditions. There is no attempt to provide actual hypotheses, data, or graphics, especially concerning cited articles published in refereed journals. The purpose of the annotation is to inform the reader of the relevance, accuracy, and quality of the sources cited. Relevance relates to the citation's presentation of environmental conditions such as ambient air temperature, sea surface conditions (wave height, wave period, wave direction, spectral distribution) tidal regime, currents, wind conditions (direction, speed, and gusts), terrain (beach gradients and obstacles), and surf zone parameters (breaker type, surf zone width, longshore currents).

II. PURPOSE

There are three main purposes behind writing this annotated bibliography. First, the annotations serve as a starting point for the development of an environmental support plan. The annotations help educate program managers on environmental impacts and force scientists and engineers to consider various authoritative methods that describe temporally and spatially variable data elements, parameters, and phenomena. Second, this annotated bibliography provides a clear understanding about what scientific advances have been applied to characterize the environment for amphibious craft and naval expeditionary warfare. After reading and critically analyzing sources, the program managers will be able to determine what issues there are and what methods applied researchers need to employ to characterize the coastal zone. Scientists and engineers involved in trade studies may also benefit from past investigations. Finally, this complete and comprehensive overview of environmental characterization efforts to support amphibious craft is being published as a NRL Memorandum Report in order to benefit other scientists and engineers involved in acquisitions, design, testing, and evaluations. There is a leaning toward remote sensing studies in this bibliography. At the time of this writing, no other annotated bibliography exists that is relevant to environmental factors impacting emerging capabilities such as the Expeditionary Fighting Vehicle, Joint Maritime Assault Connector, and Transition Craft.

III. PRINT RESOURCES

1. Abileah, Ronald. Shallow-Water Bathymetry with Commercial Satellite: A technique for more than 100 years has matured into a capability for rapid shallow-water depth mapping. *Sea Technology*, Volume 47, No. 6, Arlington, VA: Compass Publications, June, 2006.

Mr. Ron Abileah summarizes several remote sensing methods that may be applied to chart shallow water bathymetry. The most advanced is the airborne lidar bathymetry method. Other technologies are based on multi-spectral imaging of bottom reflected sunlight, or

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photobathymetry (Lyzenga, 1978); sensing wave, current, and bottom interactions with Synthetic Aperture Radar (Alpers, 1984); ocean wave refraction (Kasischke et al., 1984; Bennett 1986); and ocean wave velocity, which is referred to as wave kinematics bathymetry (WKB). The article displays WKB over an IKONOS panchromatic image of the area around Point Loma in California. Comparing results with a multibeam sonar survey Abileah determined that the following can be achieved with satellite WKB: one sigma depth errors in the range of 5-10%, horizontal resolution proportional to depth (100 m at 10 m depth), for up to a maximum depth of 25 m. Abileah also mentions that satellite techniques do not meet International Hydrographic Office survey standards. This method could be applied to estimate shallow-water bathymetry in regions where satellite archives provide simultaneous images that are less than 20 seconds apart.

2. Abileah, Ronald, Dennis M. Silva, and W. Snyder, “New Applications for Airborne and Satellite Multispectral Imagery,” *Sixth International Conference on Remote Sensing for Marine and Coastal Environments*, 2000.

This paper presents a method to subtract background clutter using multi-spectral imagery to improve the detection of pollutant effluents, monitoring of coral reefs, locating shipwrecks, and tracking marine mammals. The method uses spectral differences to distinguish the interesting objects from the clutter. In ocean imagery at least three spectral bands are recommended, and up to ten can be beneficial. The method was first proven and applied to detection of underwater mines. Imagery used in this study was acquired with several different airborne multi-spectral imaging systems, typically with 0.5 to 1 m ground resolution. Such applications highlight the ability of imagery to provide information on features that impact the maneuver of amphibious craft and vessels in shallow-water environments.

3. Allard, Richard, John Christiansen, Tom Taxon, Steve Williams and Dean Wakeham, 2002: The Distributed Integrated Ocean Prediction System (DIOPS). Proceedings of the Oceans 2002 MTS/IEEE, Biloxi, MS.

This proceedings article describes components of the Distributed Integrated Ocean Prediction System (DIOPS) including the Wave Action Model (WAM), the Simulating Waves Nearshore (SWAN) model, the US Navy Relocateable Tide and Surge Model (a.k.a. PCTIDES), and the Navy Standard Surf Model. DIOPS has been run for operational organizations at the Naval Pacific Meteorology and Oceanography Center (NPMOC) in San Diego, CA. Development of DIOPS included various data collection and modeling assessment tests that are described in numerous contractor reports. DIOPS has been demonstrated in Joint US Military Exercises such as MILLENIUM CHALLENGE 2002, Joint Task Force Exercises, and several NATO exercise such as STRONG RESOLVE/RAPID RESPONSE.

Today oceanographers involved with NPMOC are using the Coupled Ocean/Atmosphere Mesoscale Prediction System On-Scene (COAMPS-OS™) which includes the NRL Coastal Ocean Model (NCOM) and SWAN. Scripts are used to generate input files for Delft3D (developed by Delft Hydraulics), which provides a sophisticated, 3-dimensional modeling system. Delft3D can run on a laptop computer to simulate nearshore conditions anywhere in the world.

4. Alpers, Werner and Ingo Hennings, 1984. A theory of the imaging mechanism of underwater bottom topography by real and synthetic aperture radar. J. Geophys. Res., Vol. 89, 10,529-10,546.

A simple theoretical model of the imaging mechanism of underwater bottom topography in tidal channels by real and by synthetic aperture radar (SAR) is presented. The imaging is attributed to surface effects induced by current variations over bottom topography. The current modulates the short-scale surface roughness, which in turn gives rise to changes in radar reflectivity. The bottom topography-current interaction is described by the continuity equation, and the current-short surface wave interaction is described by weak hydrodynamic interaction theory in the relaxation time approximation. This theory contains only one free parameter, which is the relaxation time. It is shown that in the case of tidal flow over large-scale bottom topographic features, e.g., over sandbanks, the radar cross-section modulation is proportional to the product of the relaxation time and the gradient of the surface current velocity, which is proportional to the slope of the water depth divided by the square of the depth. To first order, this modulation is independent of wind direction. In the case of SAR imaging, in addition to the above mentioned hydrodynamic modulation, phase modulation or velocity bunching also contributes to the imaging. However, in general, the phase modulation is small in comparison to the hydrodynamic modulation. The theory is confronted with experimental data which show that to first order the theory is capable of explaining basic features of the radar imaging mechanism of underwater bottom topography in tidal channels. In order to explain the large observed modulation of radar reflectivity we are compelled to assume a large relaxation time, which for Seasat SAR Bragg waves (wavelength 34 cm) is of the order of 30-40 s, corresponding to 60-80 wave periods.

5. Bachmann, Charles M., Thomas L. Ainsworth, Robert A. Fusina, Marcos J. Montes, Jeffrey H. Bowles, Daniel R. Korwan, 2007. “Bathymetric Retrieval from Manifold Coordinate Representations of Hyperspectral Imagery,” Proceedings of IGARSS'07, Barcelona, Spain.

This work describes a method to compress look-up tables for retrieval of bathymetry from hyperspectral imagery. This approach could be used to compress the tables described in the reference by Mobley et al. (2005). Follow-on shallow-water research is being accomplished at locations such as the Virginia Coast Reserve (VCR) under the supervision of Dr. Bachmann. Preliminary results relevant to trafficability and very shallow water bathymetry were showcased at the VCR on September 20, 2007.

6. Bachmann, Charles M., M. H. Bettenhausen, Robert A. Fusina, Timothy F. Donato, A. L. Russ, J. W. Burke, G. M. Lamela, William J. Rhea, Barry R. Truitt, J. H. Porter, 2003. “A Credit Assignment Approach to Fusing Classifiers of Multi-Season Hyperspectral Imagery,” IEEE Transactions on Geoscience and Remote Sensing, 41(11):2488-2499.

This paper describes an approach to fusing models from multi-temporal hyperspectral imagery to achieve an improved land-cover classification in a coastal barrier island environment.

7. Bachmann, Charles M., C. Reid Nichols, Richard P. Mied, Ellen Bennert, Robert A. Fusina, Chung Hye Read, and Timothy Donato, 2007. Phase I Progress Report: Hydrodynamic Agents in the Littoral Environment, Naval Research Laboratory Memorandum Report, NRL/MR/7230--07-9056, 48 pp. plus Appendices.

The first phase of the Hydrodynamics Agents in the Littoral Environment (HALE) is described in this NRL Memorandum Report. Key efforts involved description of tidal processes at several potential study locations, a listing of images that were collected for the Han River Estuary, imagery analysis procedures such as satellite feature tracking, maximum cross correlation, and tracer equation inverse. These methods resulted in approximately 19 years of waterlines that were overlaid on hydrographic information pulled from Digital Nautical Chart®, current vectors overlaid on baseline Landsat and ASTER image, and an analysis of the shifting mudflats. Appendices included a listing of multi-source imagery and corresponding tide predictions. Difficulties in obtaining an adequate digital elevation model (DEM) were explained and compensated for by the generation of synthetic data. The goal involves using an imagery stack of sufficient length and a corresponding DEM that fosters building an elevation time series. The time series will then be analyzed to identify harmonic constants. This progress report may be obtained from the Maury library (228-688-4597) at Stennis Space Center, MS and at the Ruth H. Hooker Research Library (202-767-2134) in Washington, D.C. Work was funded through the InnoVision Directorate of the National Geospatial-Intelligence Agency.

8. Bachmann, Charles M., C. Reid Nichols, Richard P. Mied, Kevin J. McIlhany, Robert A. Fusina, and Patrick K. Woodward, 2007. Phase II Progress Report: Hydrodynamic Agents in the Littoral Environment, Naval Research Laboratory Memorandum Report, NRL/MR/723--07-9XXX, XX pp. plus Appendices. (In Press)

The second phase of the Hydrodynamics Agents in the Littoral Environment (HALE) is described in this NRL Memorandum Report. Key efforts involved the processing of a synthetic time series using NOAA's least squares harmonic analysis (LSQHA) program. A synthetic data set of water levels was generated that would be similar to an imagery-derived dataset. LSQHA was used to generate harmonic constants for harmonic prediction. Continued efforts were made to pull additional imagery and to extract new waterlines. Difficulties in obtaining an adequate digital elevation model (DEM) were explained and an effort was made to generate a relative DEM for the Han River Estuary. Once a quality assured DEM is made available, water level time series can be generated by merging the waterlines with the DEM. The water level time series will then be analyzed to identify harmonic constants. An error budget was estimated as a major component of the phase two effort. At the time of this writing, this progress report is in the formal review process at the Naval Research Laboratory in Washington, D.C. It will be available from the Maury library (228-688-4597) at Stennis Space Center, MS and at the Ruth H. Hooker Research Library (202-767-2134) in Washington, D.C.

During September 2007, as a component of the HALE program, a remote sensing campaign was conducted at the Virginia Coast Reserve (VCR) to develop improved classifications of the coastal zone. This work utilized land and in-water optical sensors, geotechnical instruments, and meteorological and oceanographic data obtained from surveys and a local VCR sensor suite. Research thrusts focused on assessing the quality of imagery-extracted waterlines, determining shallow water bathymetry and assessing trafficability through look-up tables derived from spectrometry, dynamic cone penetrometers, and light weight deflectometers. Work was funded through the InnoVision Directorate of the National Geospatial-Intelligence Agency.

9. Bennett, John R., 1986. An improved method for the determination of water depth from surface wave refraction patterns. Proc. of IGARSS'86 Symposium, Zurich (8–11 September).

This frequently cited paper provides a mathematical model for using wave refraction observations to determine water depth from a synthetic aperture radar. The model assumes that the waves are long-crested and obey linear theory, that the currents are negligible, and that there is a single dominant frequency. In principle, under these assumptions, the wavenumber magnitude alone is sufficient to determine the depth using the dispersion relation. However, observations of wavelength and direction will not necessarily obey the basic assumptions which lead to this relation. Therefore, before determining the depth from the dispersion relation, the model filters the data so that it is consistent with the theory. The method is tested against Seasat data from the Diamond Shoals region of Cape Hatteras.

10. Bird, Eric C.F., and Maurice L. Schwartz. *The World's Coastline*, New York: Van Nostrand Reinhold Company, 1985.

Coastal geomorphology is described in an around-the-world sequence for 135 different locations starting with Alaska and proceeding counterclockwise around the Americas to Arctic Canada. Greenland and Iceland are then described, and another counterclockwise sequence begins with Norway, proceeding by way of Europe and the Mediterranean, around Africa to India, Southeast Asia, China, Korea, and the Pacific and Arctic coastlines of Russia. This work describes inland water bodies such as the Great Lakes and the Caspian Sea. The sequence is completed by way of the Philippines, Indonesia, Papua New Guinea, Australia, New Zealand, the islands of the Pacific, Atlantic, and Indian Oceans, and finally Antarctica. This book provides photographs and diagrams depicting the extent of marshes and swamps, beach slopes, and key terrain features. It is a good starting point for terrain analysis and has been used consistently by the Naval Oceanographic Office in the production of Mine Warfare Pilots and environmental support packages. This work could be modernized by building a database of extracted satellite and aerial imagery features using imagery archives that are maintained by the National Geospatial-Intelligence Agency.

11. Boyd, Jeremy D., 2006. Evaluation of ADCP Wave Measurements, Masters Degree Thesis, Monterey, CA: Naval Post Graduate School, 52 pp.

The Teledyne Workhorse Sentinel acoustic Doppler current profiler (ADCP), which measures both pressure and velocity, was evaluated as a wave gauge. Using a current meter to measure waves involves the analysis of pressure and velocity components. This "PUV method" is well known and the author cites the use of electromagnetic current meters to measure waves in shallow water. The InterOcean S4 current meter with a Paroscientific pressure sensor is an example of an electro-magnetic current meter used to measure currents and waves in shallow water. The premise behind the PUV gauge is the processing of pressure readings (water level) and determining the variation in pressure in the velocity where the x-direction (east-west) is the u-component and the y-direction (north-south) is the v-component. The author compared the wave frequency spectrum, mean direction, and directional spread from the ADCP with those from a nearby Datawell Waverider directional wave buoy. The author reports that the ADCP results suffered from low signal to noise ratios in low energy conditions and deeper water. He found that wave height estimates were sensitive to these errors, but wave direction estimates were surprisingly robust.

12. Browne, Matthew, Darrell Strauss, Rodger Tomlinson, and Michael Blumenstein, 2006. Objective beach-state classification from optical sensing of cross-shore dissipation profiles, IEEE Transactions on Geoscience and Remote Sensing, Vol. 44, Issue: 11, 3418-3426 pp.

Remote sensing using terrestrial optical charge-coupled device cameras is a useful data collection method for geophysical measurement in the nearshore zone, where *in situ* measurement is difficult and time consuming. In particular, optical video sensing of the variability in human-visible surface refraction due to the nearshore incident wave field is becoming an established method for distal measurement of nearshore subtidal morphology. The authors report on the use of a low-mounted shore-normal camera for gathering data on cross-shore dissipative characteristics of a dynamic open beach. Data are analyzed for the purposes of classifying three of Wright and Shorts' intermediate classes of morphological beach state as determined by expert raters. Although these beach states are usually thought of as being distinctive in terms of their longshore bar variability, theory predicts that differences should also be observed in cross-shore dissipative characteristics. Three methods of generating features from statistical features from the archived optical data are described and compared in terms of their ability to discriminate between the beach states. Principal component scores of the percentile distributions were found to provide slightly better classification performance (i.e., 85%, while approximating the data using relatively fewer features), whereas classification using intensity distributions alone resulted in the worst performance, classifying 78% of beach states correctly. Class center moment profiles for each beach state were constructed, and results indicate that cross-shore wave dissipation becomes more disorganized as linear bars devolve into more complex transverse structures.

13. Dowling, George B., Garrett G. Salsman, Marshall D. Earle, and Eileen P. Kennelly, Surf Zone Characterization for the EATD Explosive Neutralization System, 1993. A&T Technical Report No, 93-505 for the Coastal Systems Station, Panama City, Florida, 45 pp.

This report for the Explosive Neutralization Enhanced Advanced Technology Demonstration Program was focused on characterizing shallow water surf zones to support the launching of line charges across the surf zone. Modeling efforts focused on quantifying dimensions of the surf zone and wait times, that is, the probability that a Landing Craft Air Cushion will encounter a maximum breaker height within a specified time. A major innovation involved the development of probability distributions of beach gradients given a database containing information on 242 beaches, worldwide. Beach gradients were estimated using the equilibrium beach profile. This work provided a foundation for new work to support design of amphibious craft that transition from a planing hull to an amphibious tractor at approximately the 6 m curve, the Expeditionary Fighting Vehicle (see Earle and Kennelly, 1995). This work to characterize surf zones was completed by Analysis & Technology Inc. under contract N61331-92-D-0042/0047.

14. Earle, Marshall D.,1999, Applied and operational surf modeling. *Shore and Beach*, **67**, 1999, 70-75.

A general overview of techniques used to model waves and surf. The development of the Navy Standard Surf Model (NSSM) is explained and descriptions are provided for complementary models and sensors which support surf zone modeling. The NSSM outputs information that would be estimated by surf observations as described in the Navy's Joint Surf Manual, which was released on 02 January 1987 as COMNAVSURFPAC/COMNAVSURFLANT INSTRUCTION 3840.1B. *Shore and Beach* is the Journal of the American Shore and Beach Preservation Association.

15. Earle, Marshall D. and Eileen P. Kennelly, 1995. Water Mobility Environmental Support for the Advanced Amphibious Assault Vehicle (AAAV), Vol. 1: Surf Conditions, Vol. 2: Probability Distributions of Surf Parameters, report for NRL-SSC and Office of the Direct Reporting Program Manager-Advanced Amphibious Assault, 31 pp. (Vol. 1), 141 pp. (Vol. 2).

This two-part report to define surf zone parameters was completed by Neptune Sciences under contract to the Naval Research Laboratory for the Direct Reporting Program Manager for Advanced Amphibious Assault. Surf conditions for potential landing beaches were estimated given a range of incident wave conditions. Methods involved determining incident wave conditions, developing approximate beach profiles, running the Navy Standard Surf Model, performing statistical analyses, performing surf calculations at representative sites, and completion of a sensitivity analysis of input parameters such as beach profile. Representative sites were determined by generating a probability distribution of beach gradients that were developed using a database containing information on 242 beaches, worldwide. Beach gradients were estimated using the equilibrium beach profile. Surf model output included significant breaker height, maximum breaker height, surf zone width, number of surf lines, dominant breaker type, maximum longshore current, and distance to maximum longshore current. The second volume of this work provides probability distributions for the surf zone parameters discussed in Volume 1. This report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

16. Earwaker, Karen L., C. Reid Nichols, and W. Todd Ehret, 1995. Special 1995 tidal current predictions for Galveston Bay, Texas, NOAA Technical Memorandum NOS OES 014, Office of Ocean and Earth Sciences, NOS, NOAA, Silver Spring, MD, 18 pp. + Appendices.

A general report describing quality assurance tests of traditional tidal current predictions with current meter data. Approximately 30-days of acoustic Doppler current profiler data were used to update the harmonic constituents for Galveston Bay. The report includes time series plots, scatter diagrams of u- and v-components, harmonic constant tables, new predictions, and plots of residuals. The residual is the difference between the new predictions and the observations.

17. Evans, C. T., 1994. Analysis of a Three-Beam Radar as an Instrument for Determining Ocean Wave Heights and Vector Slopes, University of Kansas Radar Systems and Remote Sensing Laboratory Technical Report 8621-5.

The Vector Slope Gauge (VSG) is a 35-GHz FM-CW scatterometer that has the unique capability of simultaneously (nearly) measuring the range and backscattered power to three points on the ocean surface. With three ranges and knowledge of the experimental geometry, the wave height at each footprint can be obtained. The three footprints form a plane surface, which enable two orthogonal slope components to be obtained. Obtaining the slope of ocean waves is important because it is correlated with the backscattered power. By obtaining the vector slope, one does not have to make any assumptions about the linearity or "long-crestedness" of the ocean waves. With a time series record of ocean wave heights and slopes, one can learn a great deal about the ocean surface. Spectral analysis of the recorded time series yields information about the wave height power spectral density, the mean wave direction vs. frequency, and the directional width spectrum. The results from the VSG are similar to those obtained from a pitch-and-roll buoy. In addition, since the slope distribution of ocean waves is nearly normal, the moments of a bivariate normal distribution can be used to fit an ellipse to the wave slopes.

18. Greenslade, Diane J. M., 2001. The assimilation of ERS-2 significant wave height data in the Australian region. Journal of Marine Systems 28:141-160.

This paper by Dr. Greenslade from the Bureau of Meteorology Research Center in Australia describes work to assimilate satellite altimeter significant wave height (SWH) data into an ocean wave model. Data from the Earth Resources Satellite 2 (ERS-2) were used. Statistical interpolation was used to construct analyzed SWH fields using the altimeter data. The ocean wave model was WAM (cycle 4), run operationally at the Australian Bureau of Meteorology and providing up to 36-hour forecasts of sea-state for the oceans around Australia. It consists of a global model at 3^o resolution and a nested version for the Australian region at 1^o resolution. Forcing was obtained from surface wind fields calculated from the global and regional atmospheric systems. Model spectra were adjusted using various assimilation strategies. Results were validated against a number of waverider buoys situated around the Australian coast. Over two 35-day periods, it was found that assimilation of the ERS-2 SWH data reduced the systematic bias in analysed SWH and wave peak period by approximately 15% and 35% respectively. The *rms* error was reduced by approximately 7% and 3% respectively.

19. Hayslip, Alfonso R., Joel T. Johnson, and Gregory R. Baker, 2003. Further Numerical Studies of Backscattering from Time-Evolving Nonlinear Sea Surfaces. IEEE Transactions on Geoscience and Remote Sensing, 41(10);2287-2293.

In this paper, L-band Doppler spectra with a numerical model are reported for wind speeds up to 5.0 m/s through the use of a curvature filter to reduce these steep short waves. The higher wind speed results show significant deviations from those reported with a linear hydrodynamic model, including increased spectral broadening and polarization dependencies. There are numerous other investigations relevant to the development of coherent L-band radar to measure the properties of short surface waves, especially in the coastal environment.

20. He, Yijun, Hui Shen, and Will Perrie, 2006. Remote sensing of ocean waves by polarimetric SAR. Journal of Atmospheric and Oceanic Technology, 23(12):1768-1773.

A new method to measure ocean wave slope spectra using fully polarimetric synthetic aperture radar (POLSAR) data were developed without the need for a complex hydrodynamic modulation transform function. There is no explicit use of a hydrodynamic modulation transfer function. This function is not clearly known and is based on hydrodynamic assumptions. The method is different from those developed by Schuler and colleagues or Pottier but complements their methods. The results estimated from NASA Jet Propulsion Laboratory (JPL) Airborne Synthetic Aperture Radar (AIRSAR) C-band polarimetric SAR data show that the ocean wavelength, wave direction, and significant wave height are in agreement with buoy measurements. The proposed method can be employed by future satellite missions such as *RADARSAT-2*.

21. Holland, K. Todd, 2001, Application of the Linear Dispersion Relation with Respect to Depth Inversion and Remotely Sensed Imagery, IEEE Transactions On Geoscience And Remote Sensing, Vol. 39, No. 9.

Remote sensing methods have been developed to estimate bathymetry through the use of a theoretical relationship between wave speed and water depth known as the linear, finite depth, dispersion equation for surface gravity waves. We describe a validation effort encompassing several hundred observations of wavenumber magnitude for sea-swell frequencies obtained over a wide variety of conditions to investigate possible error sources resulting from the practical application of this relationship. These wavenumber estimates were computed from pressure gauge signals using signal processing algorithms that can be equivalently applied to measurements of wave phase as imaged through remote sensors. The major goal was to determine the accuracy of the dispersion relation while attempting to minimize errors associated with sensor positioning, tidal variations, and Doppler shifts due to mean currents. For water depths outside the surf zone, the linear dispersion relation is highly accurate, with average depth estimation errors on the order of 3–9% of the observed depth. In shallower regions, nominally less than 4 m for this field site, where wave breaking is evident and nonlinear shoaling effects are more pronounced, normalized depth errors of over 50% were commonly observed with most predictions being deeper than observations. Strong correlation between these bias errors and measured wave heights emphasizes the importance of accounting for wave amplitude in the calculation of shallow water phase speeds for depth estimation. A simple depth correction is provided to allow for bathymetry estimation within the surf zone.

22. Holland, K. Todd, Robert A. Holman, Thomas C. Lippmann, John Stanley, and Nathaniel Plant, 1997. Practical Use of Video Imagery in Nearshore Oceanographic Field Studies, IEEE Journal of Oceanic Engineering, Vol. 22, No. 1.

An approach was developed for using video imagery to quantify, in terms of both spatial and temporal dimensions, a number of naturally occurring (nearshore) physical processes. The complete method is presented, including the derivation of the geometrical relationships relating image and ground coordinates, principles to be considered when working with video imagery and the two-step strategy for calibration of the camera model. The techniques are founded on the principles of photogrammetry, account for difficulties inherent in the use of video signals, and have been adapted to allow for flexibility of use in field studies. Examples from field experiments indicate that this approach is both accurate and applicable under the conditions typically experienced when sampling in coastal regions. Several applications of the camera model are discussed, including the measurement of nearshore fluid processes, sand bar length scales, foreshore topography, and drifter motions. Although we have applied this method to the measurement of nearshore processes and morphologic features, these same techniques are transferable to studies in other geophysical settings.

23. Hoyt, John G. III, 2006. Interpretation of the Performance of the Expeditionary Fighting Vehicle in the Ocean and Surf Environments, NSWCCD-50-TR-2006/044, West Bethesda, MD: Naval Surface Warfare Center-Carderock Division, 60 pp.

This technical report provides the engineering basis for the evaluation of the hydrodynamic performance of the Expeditionary Fighting Vehicle (EFV) in both the open ocean and surf environments. The paper discusses frequency response relationships between specified sea and surf conditions versus what is observed in the coastal ocean. In order to measure sea and surf conditions, wave buoys and pressure sensor (surf height) arrays are recommended, respectively. The author describes Datawell Waverider directional wave buoy output and describes how the 0.6 Hz “cut-off” frequency is associated with a wavelength of 14 ft, half the EFV’s length in water mode. Analysis of surf array data yields average height, peak height, minimum height, beat frequency, the number of breaker lines in the surf, and surf zone width. Recommended methods for the measurement and interpretation of waves are provided including the estimation of sea and surf conditions not available during testing. Recommendations relate to normalizing significant wave height and considering average surf height.

24. Huang, Weimin, Shicai Wu, Eric Gill, Biyang Wen, and Jiechang Hou, 2002. HF Radar Wave and Wind Measurement over the Eastern China Sea, 40(9):1950-1955.

High-frequency (HF) radar can be employed to measure sea surface state parameters such as wave height, windfield, and surface current velocity. This paper describes the application of the HF ground wave radar in remote sensing the surface conditions over the Eastern China Sea in October 2000. The radar, referred to as the OSMAR2000, was developed by Wuhan University. Preliminary wave spectra, wave heights, and wind fields estimated from the collected data are presented and compared with ship-recorded measurements where such are available. The range for wind direction sensing is up to 200 km. Wave information and wind speed can be provided up to a range of 120 km. The mean difference between radar- and ship-measured significant wave height is 0.323 m; wind direction is measured within 20^{o}; and wind speed to within 0.6 m/s. With such agreement being fairly reasonable, the feasibility of the inversion algorithm and the ocean state real-time sensing capability of OSMAR2000 are demonstrated.

Other HF radars include the SeaSonde, which was developed by CODAR Ocean Senors, and the Ocean Surface Current Radar or OSCR, which has been demonstrated at the South Florida Ocean Measurement Center (SFOMC). The NOAA National Data Buoy Center provides links and information on HF Radar which remotely measure ocean surface currents (See URL: http://hfradar.ndbc.noaa.gov/). They could be used to characterize currents and waves during design tests and operational assessments. The radars' performance could be degraded by obstacles in their field of view and in the vicinity of the radar antennas. Other options for environmental monitoring that supports amphibious craft relates to Over-The-Horizon Radar, which are often used to support drug interdiction surveillance.

25. Hwang, Paul A., 2005. Wave number spectrum and mean square slope of intermediate-scale ocean surface waves. Journal of Geophysical Research, 110(C10029): 1-7.

This paper presents an analysis of the wave number spectra of intermediate-scale waves (wavelengths between 0.02 and 6 m) covering a wide range of wind and background wave conditions under various sea-state conditions. The main result of the analysis is that the dependence of the dimensionless wave spectrum on the dimensionless wind friction velocity follows a power law function. The coefficient and exponent of the power law function vary systematically with the wave number. The wave number dependence of the coefficient and exponent serves as an empirical parameterization for computing the wave number spectra of intermediate-scale waves at different wind speeds. Calculation of the mean square slope from the resulting wave number spectrum confirms that intermediate-scale waves are the dominant contributor of the ocean surface roughness. A simple formula is presented for calculating the band-pass filtered mean square slope of the ocean surface for remote sensing applications. Paul A. Hwang works in the Remote Sensing Division at the Naval Research Laboratory in Washington, D.C.

26. Hwang, Paul A., William B. Krabill, Wayne Wright, Robert N. Swift, and Edward J. Walsh, 2000. Airborne Scanning Lidar Measurement of Ocean Waves. Remote Sensing of Environment, Vol. 73, pp 236–246.

A scanning lidar system provides high-resolution, two-dimensional measurements of ocean wave displacement. The fact that it is an airborne operation further enhances the speed of data acquisition. These properties allow rapid characterization of the ocean wave environment. In addition to active ranging, the scanning optics can obtain passive measurements of surface emissivity, yielding a digital image of surface brightness in real time. Processed into a binary image, these measurements can provide information on the average statistics and the spatial distribution of breaking waves. Technical specifications of the system and examples of the application are described.

27. Jain, Atul, 1977. Determination of ocean wave heights from synthetic aperture radar imagery, Applied Physics, 13, 331.

A calculation is presented for the cross-correlation of the radar images obtained by processing the same signal data over different portions of the chirp spectrum bandwidth as a function of the center frequency spacings for these portions. This is shown to be proportional to the square of the product of the characteristic function for ocean wave heights and the pupil function describing the chirp spectrum bandwidth used in the processing. Measurements of this function for ocean wave imagery over the coast of Alaska, the North Atlantic, and Monterey Bay, California, and correlation with the significant wave heights reported from ground truth data indicate that the synthetic aperture radar instrument can be used for providing wave height information in addition to the ocean wave imagery. This work was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under Contract NAS 7-100, sponsored by the National Aeronautics and Space Administration.

28. Karaev, Vladimir Yu, M. B. Kanevsky, G. N. Balandina, Peter Challenor, Christine Gommenginger, Meric Srokosz, 2005. The concept of a microwave radar with asymmetric knife-like beam for the remote sensing of Ocean Waves. *Journal of Atmospheric and Oceanic Technology, 22* (11), 1810-1821.

This paper documents a major advance in remote sensing since spaceborne radar systems do not measure surface wave slopes, and this uncertainty leads to errors in applications such as wind-speed retrieval. Innovations relate to the measurement of sea-surface wave processes to more accurately determine surface wind speed. This research study documents the use of a satellite-borne microwave radar with a knife-like beam (1° × 25°–30°) to measure the variance of surface wave slopes. This approach is viable when installed on aircraft, but encounters a major problem for space-borne implementation because of its large “footprint” on the ocean surface. Follow-on research and development relates to range selection and processing procedures that synthesize data in order to achieve the spatial resolution required to study wave processes on the ocean surface from a satellite. This effort documents that microwave radars at and near nadir can make direct measurements not only of significant wave height but also of the surface wave slopes. Much of this work was supported by Russian Foundation of Basic Research, grant 03-05-64259 and 03-05-64260. It was also presented at an annual meeting of the Union Radio-Scientifique Internationale or URSI.

29. Karaev, Vladimir Yu, M. B. Kanevsky, G. N. Balandina, E. M. Meshkov, Peter Challenor, Meric Srokosz, Christine Gommenginger, 2006. A rotating knife-beam altimeter for wide-swath remote sensing of ocean: Wind and waves. Sensors 6(6):620-642.

The use of a nadir altimeter radar with a rotating knife-beam antenna pattern is considered for improved measurements of the sea surface wind and wave parameters over a wide swath. Theoretical calculations suggest the antenna beam rotating about the vertical axis is able to provide wide swath of order 250-350 km. Processing of the signals using time or Doppler sampling techniques results in the division of the antenna footprint into elementary scattering cells of the order of 14x14 km. The theoretical algorithms developed here indicate that the system may be used to retrieve the variance of large-scale slopes, the direction of wave propagation and the wind speed in each cell. The possibility of measuring significant wave height is also analyzed. The combination of linear motion of the radar and the rotation of the knife-beam antenna can be exploited to build up a two-dimensional map of the surface, which enables better understanding of wave processes and to study their structure and temporal dynamics using repeated observations.

30. Kasischke, E.S., Guy A. Meadows, and Philip L. Jackson, 1984. The use of synthetic aperture radar imagery to detect hazards to navigation. ERIM Report 169200-2-F to Defense Mapping Agency, Ann Arbor, MI. 194 pp.

There are many papers on satellite imagery of oceans and several (Abileah 2000, 2006; Bennett 1986; Lyzenga, 1978, 2006) have been highlighted in this bibliography since they have been applied in Naval Research Laboratory activities involving coastal characterization. Practical impediments have limited the versatility of these approaches owing to optical penetrability to the bottom and the availability of aircraft platforms to be used in denied areas. In addition most approaches are based either on surface wave kinematics, or the physics of bottom reflectivity; but not both. This paper identifies a method of analysis based on wave refraction and one image while Abileah's formulation requires two images.

31. Lachman, Lawrence M., 2006. Surf Zone Modeling for an EFV Trainer for the USMC, Paper No. 2816, I/ITSEC 2006 Proceedings, Interservice/ Industry Training, Simulation and Education Conference Proceedings, December 4-7, Orlando, Florida.

A paper describing the training simulation for the Expeditionary Fighting Vehicle by MultiGen-Paradigm and HART Technologies under a contract from General Dynamics Amphibious Systems. The paper discusses the training system, the full set of surf zone requirements, and creative solutions to cope with a seamless transition from deep water to shallow water to the shoreline. In the simulation, the water tapers to zero height at zero depth, visual cues show that the wave has broken or spilled into the trough of the wave, near vertical

wave fronts result as a function of the bottom depth, controls for slope of the littoral zone, and sand bars with a shallower depth than the surrounding area.

32. Lyzenga, David R., 1978. Passive remote sensing techniques for mapping water depth and bottom features. Applied Optics, 17, No. 3, pp 379–383.

Ratio processing methods are reviewed, and a new method is proposed for extracting water depth and bottom type information from passive multi-spectral scanner data. Limitations of each technique are discussed, and an error analysis is performed using an analytical model for the radiance over shallow water. This continues to be an active area of research where progress in the very shallow water regions may be made by hyperspectral imagery.

33. Lyzenga, David R., Norman P. Malinas, and Fred J. Tanis, Multispectral Bathymetry Using a Simple Physically Based Algorithm, IEEE Transactions on Geoscience and Remote Sensing, Vol. 44, No. 8, August 2006

A simple method for estimating water depths from multi-spectral imagery is described and is applied to several IKONOS data sets for which independent measurements of the water depth are available. The methodology is based on a physical model for the shallow-water reflectance, and is capable of correcting for at least some range of water-quality and bottom-reflectance variations. Corrections for sun-glint effects are applied prior to the application of the bathymetry algorithm. The accuracy of the depth algorithm is determined by comparison with ground-truth measurements, and comparisons between the observed and calculated radiances are presented for one case to illustrate how the algorithm corrects for water-attenuation and/or bottom-reflectance variations.

34. MCCDC, 1990. The Persian Gulf Region, A Climatological Study, FMFRP 0-54, Department of the Navy, Headquarters, United States Marine Corps, Marine Corps Combat Development Command, Quantico, VA, 62 pp.

This Fleet Marine Force Reference Publication has been used as a planning document to consider the impacts of climatological measures on missions in South West Asia. The publication describes the physical geography and the monsoon climate. It is a general document that was produced in 1988 by the U.S. Air Force. It provides relevant climatological information on mean conditions.

There are other planning manuals similar to FMFRP 0-54 that are associated with geographic or geospatial intelligence. For example, Marine Corps Warfighting Publication (MCWP) 3-35.7, *MAGTF Meteorological and Oceanographic Support*, provides the information needed by Marines to understand, plan, and conduct Marine Air-Ground Task Force (MAGTF) meteorological and oceanographic (METOC) operations. The focus of MCWP 3-35.7 is METOC effects on operations and missions. It addresses METOC planning requirements, command relationships, METOC support capabilities, and external support requirements.

35. McDermid, Jack G., Daphne Frilot. Julie Bosch, Josie P. Fabre, Jacque Veglie, and Cheryl Szydlik, 1996. Summary of Expeditionary/Amphibious Warfare Environmental Support Capabilities, Neptune Sciences Report to NRL-SSC, 188 pp.

A draft report for publication as a NRL professional paper describing warfare areas, state-of-the-art models, oceanographic instruments, and tactical decision aids. This work provides technology forecasts and research thrusts. It provides program managers with a snapshot of what capabilities can be matched to specific littoral information needs. The deliverable Neptune Sciences, Inc. technical report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

36. McDermid, Jack G., Marshall D. Earle, Dennis C. Herringshaw, Shane M. Mayfield, and C. Reid Nichols. METOC Conditions affecting AAAV Ship-To-Objective Maneuver: A Detailed Analysis of Power Projection Points Sited Along Iranian and Korean Coasts, NRL Memorandum Report NRL/MR/7170--97-8060, Naval Research Laboratory, Stennis Space Center, MS, July, 1997, 72 pp. plus appendices.

This Memorandum Report was written as a layman's guide to waves, tides, and shallow-water processes by oceanographers from Neptune Sciences, Inc. (NSI). NSI is no longer in business and several people that participated in this technical writing project are still working on applied oceanography tasks. This work was completed under a contract supervised by Mr. Jack McDermid from the Naval Research Laboratory in Stennis Space Center, Mississippi. The report was completed by summarizing descriptive information relevant to the littoral battlespace and by using encyclopedic information and numerical models to statistically describe deep water waves and surf along a particular site found on the Southeast Iranian Coast and the Northeast Korean Coast. Material in this report was used by the Water Mobility Integrated Product Team and by several action officers who were involved in wargaming. This general reference may be obtained from the Maury library (228-688-4597) at Stennis Space Center, MS and at the Ruth H. Hooker Research Library (202-767-2134) in Washington, D.C.

More detailed information can be obtained from classic references such as the 1964 title, *Waves and Beaches: The Dynamics of the Ocean Surface* by Willard Bascom. This now out-of-print book was published by Anchor Books, Doubleday and Company, Inc. in Garden City, New York. Another reference from 1966 is *Principles of Physical Oceanography* by Gerhard Neumann and Willard J. Pierson Jr., which was published by Prentice-Hall in Englewood Cliffs, New Jersey.

37. Mettlach, Theodore R., Marshall D. Earle, George B. Dowling and Garrett G. Salsman, 1998. Characterization of Surf Zone Width for Neutralization Systems, NSI Technical Report prepared for Coastal System Station, Panama Florida under contract from Naval Research Laboratory-Stennis Space Center, 40 pp., plus appendices.

Investigators from Neptune Sciences, Inc. completed an analysis of the variability of surf zone widths over representative depth profiles. A major component of this work involved modernizing the Navy Standard Surf Model. A database of potential landing beaches was used (see Earle and Kennelly, 1995) over various tidal conditions. Nearly 200 surf models rune were executed and analyzed to develop statistical results. Appendices include descriptions of surf model updates and surf zone optimization for percent breaking. The deliverable Neptune Sciences, Inc. technical report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

38. Mettlach, Theodore R., Daniel A. Osiecki, Marshall D. Earle, George B. Dowling and Garrett G. Salsman, 1998. Wave Spectrum Modifications from the Near Offshore to the Surf Zone, NSI Technical Report prepared for Coastal System Station, Panama Florida under contract from Naval Research Laboratory-Stennis Space Center, 46 pp.

Investigators primarily from Neptune Sciences, Inc. described transformation of directional wave spectra from near shore locations to the outer edge of the surf zone. This work applies linear wave theory and makes the assumption that bottom contours are straight and parallel to the general orientation to the beach. Examples of spectrum modification from intermediate to shallow water are provided. One example illustrates transformation of the theoretical Pierson-Moskowitz spectrum and another illustrates transformation of a spectrum derived from measurements. The appendix provides information on running the spectral transformation FORTRAN program. The deliverable Neptune Sciences, Inc. technical report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

39. Mettlach, Theodore R., Marshall D. Earle, George B. Dowling and Garrett G. Salsman, 1998. Characterization of Wave Height Wait Times for Mine Neutralization Systems, NSI Technical Report prepared for Coastal System Station, Panama Florida under contract from Naval Research Laboratory-Stennis Space Center, 43 pp.

Investigators primarily from Neptune Sciences, Inc. provide a detailed analysis of wait times and their probabilities between higher waves and breakers for a significant wave height of 4.7 feet. This involved application of a theoretical joint probability distribution function, simulations based on wave spectra, and actual time series. The distribution of wait times has characteristics of a Poisson process. Appendices include a joint wave height-period probability distribution, time series simulations from a wave spectrum, and buoy displacements from NDBC heave acceleration measurements. The deliverable Neptune Sciences, Inc. technical report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

40. Michel, Walter H. Sea Spectra Revisited, *Marine Technology,* Vol. 36, No. 4, Winter 1999, pp. 211-227.

This article published in the journal of the Marine Technology Society provides a useful primer on the various idealized spectra that are used to represent sea states. Developments in the formulation of sea spectrum are described from those considering one parameter such as the Pierson-Moskowitz spectra to those of multiple parameters such as the Ochi spectra. This paper is especially important since there are many oceanography and engineering textbooks that discuss specific spectra and their characteristics. For example, Ulak (2006) discusses the JONSWAP Spectrum and the Bretschneider spectra which relate to significant wave height and dominant wave period maps that were utilized to support the design of the optimal “Focused Mission Ship” hullform. Many wave models apply the Pierson-Moskowitz spectra, which was first proposed in 1964 and assumes that if the wind blew steadily for a long time over a large area, the waves would come into equilibrium with the wind. This is the concept of a fully developed sea. Advances from Pierson-Moskowitz spectra relate to the finding that wave spectra are never fully developed and continue to develop through non-linear, wave-wave interactions even for very long times and distances. The 15th International Towing Tank Conference (ITTC) during 1978 recommended the Bretschneider spectrum (two parameter spectrum, significant wave height and model frequency) for average sea conditions.

Additional information on waves and their applications can be obtained from *Waves in Ocean Engineering* by Malcom J. Tucker and E. G. Pitt. This is a fundamental textbook reference for design applications and was published by Elsevier in 2001. *Waves in Ocean Engineering* is especially applicable since it discusses the measurement of waves, including remote sensing; the analysis and interpretation of wave data; estimating the properties of the extreme "Design Wave", as well as generalizing waves for fatigue calculations; waves in finite depth, wave generation by wind and wave forecasting models; non-linear effects, and errors and uncertainties in wave data.

41. Middleditch, Andrew and Lucy R. Wyatt, 2006. An Instantaneous-Frequency Filtering Technique for High-Frequency Radar Oceanography. IEEE Journal of Oceanic Engineering, 31(4): 797-803.

High-frequency (HF) radar systems are remote sensing tools that can be used to measure oceanographic parameters. Problems can occur when using the conventional periodogram (PG) method for computing power spectral estimates from backscattered radar signals. Temporal and spatial inhomogeneities within the radar measurement region can cause distortion in the spectra. This paper describes an instantaneous-frequency (IF) filtering technique that has been developed to measure the first-order modulation contained within the radar signal. Successful removal of this modulation is shown to yield an increased quality and quantity of ocean measurements.

42. Mobley, C. D., W. P. Bissett, Jeffrey H. Bowles, Curtis O. Davis, T. V. Downes, A. Gleason, D. D. R. Kohler, Robert A. Leathers, E. M. Lochard, Marcos J. Montes, R. P. Reid, L. K. Sundman, 2005. Interpretation of hyperspectral remote-sensing imagery via spectrum matching and look-up tables, Applied Optics, 44(17): 3576-3592

This work describes a spectral look-up table approach to the retrieval of water column parameters including bathymetry, bottom type, and the concentration of in water constituents such as suspended sediments, color-dissolved organic matter (CDOM), chlorophyll, and phytoplankton. A software instantiation of this approach has been developed by the NRL Coastal and Ocean Remote Sensing Branch. These techniques are relevant in very shallow water and have been recently re-investigated at the Virginia Coast Research by the Remote Sensing Division at the Naval Research Laboratory in Washington, D.C.

43. National Research Council, 2003. Environmental information for naval warfare. Washington, D.C.: The National Academies Press.

A document describing the naval meteorological and oceanographic (METOC) organization, its successes and its limitations in providing relevant environmental information to U.S. Navy and Marine Corps forces. The main point seems to involve reshaping the METOC community to support network-centric operations. Such an idea might require METOC officers to become more engaged in modeling and remote sensing and the computer facilities and networks that enable data collection, storage, and dissemination. Appendices describe mission

areas, terms such as ocean modeling and prediction, and list environmental factors that impact specific mission areas such as amphibious warfare.

44. Naval Research Laboratory, 1994. Northern Arabian Sea Regional Conflict Environmental Assessment Guide for Selected Areas, NRL/AE/7170—93-001, Naval Research Laboratory, Stennis Space Center, MS.

A classified work completed by Neptune Sciences Inc. describing environmental factors common to the Northern Arabian Sea. Data and information from this report was added to the M&S Resources section of the Navy Modeling & Simulation Office website. This classified reference may be obtained from the Maury library (228-688-4597). The point of contact to discuss this effort is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

45. Naval Research Laboratory, 1995. North and South Korea Regional Conflict Environmental Assessment Guide for Selected Areas, NRL/AE/717X—9X-000X, Naval Research Laboratory, Stennis Space Center, MS.

This is a classified work completed by scientists and oceanographers from Neptune Sciences Inc. It describes environmental factors that are common to the east and west coasts of the Korean peninsula. This classified reference may be obtained from the Maury library (228-688-4597). The point of contact to discuss this effort is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

46. Neptune Sciences, Inc., 1997. Littoral Currents Database for Minewarfare Campaign: Assessment of Readily Available Currents.

This Neptune Science Inc. data report was the initial task in the development of a Littoral Currents Database. The report was completed under Naval Research Laboratory contract number N00014-94-C-6024 and describes the inventory of data and reference materials that were gathered to build the Littoral Currents Database. This report is stored in the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

47. Neptune Sciences, Inc., 1996. METOC Conditions for Naval Air Station, Patuxent River. Technical Report to Office of the Direct Reporting Program Manager Advanced Amphibious Assault, 60 pp.

A compendium of working papers describing environmental planning factors for tests and evaluations planned for the Chesapeake Bay. Climatological information to include tide and current predictions and wave statistics were provided to support the testing of scale models. This report is stored in the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

48. Nichols, C. Reid, 1993. Operational characteristics of the Tampa Bay Physical Oceanographic Real-Time System, In Proceedings, International Conference on HydroScience & Engineering, Volume 1, part B, Washington, D.C., pp. 1491-1498.

This paper discusses the development of physical oceanographic real-time systems or PORTS® by the National Ocean Service. PORTS® are fully-integrated and operational suites of environmental sensors that telemeter data in real-time to a data acquisition system using packet radio. The data acquisition system is linked to a data dissemination system that serves information on waves, tides, tidal currents, winds, and temperatures to users who access the system by cell phone or personal computer. This article describes the utility of the system to provide information on water level changes around Tampa Bay during Hurricane Andrew. Such a system could be deployed to mark boat lanes and provide environmental information during ship to objective maneuver (For current information on PORTS® see www.noaa.gov).

49. Nichols, C. Reid, 1994. Special 1994 tidal current predictions for Aransas Pass, Corpus Christi, Texas, NOAA Technical Memorandum NOS OES 008, Office of Ocean and Earth Sciences, NOS, NOAA, Silver Spring, MD, 15 pp. + Appendix.

This paper discusses the quality assurance of tidal currents at Aransas Pass and procedures used to update the tidal current tables based on an approximately 30-day record of acoustic Doppler current profiler data. These methods could be applied at-sea to update tidal currents at the entrance to major rivers, coastal inlets, and seabases.

50. Nichols, C. Reid, 1997. METOC Applications for System Development and Acquisition, in Douglas M. Magoffin (Ed.), Scientific and Technical Intelligence Review, Issue 2 - 1997, MCIA-1837-002-97, Marine Corps Intelligence Activity, Quantico, VA, pp 1-3.

This report highlights sea states off the east coast of Korea based on ship observations. The article describes the use of databases and models available to the meteorology and oceanography community that can be used to assess waves and surf. Discussions are relevant to ship-to-objective maneuver and development of specifications relevant to Expeditionary Fighting Vehicle performance.

51. Nichols, C. Reid. Wave, Tide, and Weather Measurements during JTFEX 97-3 at Onslow Bay, NC. NSI Data Availability Summary to Naval Research Laboratory, Stennis Space Center and Space and Naval Warfare Systems Command, May 1998.

This report describes data that was collected to assess the skill of integrated wave models such as WAM, STWAVE, REFDIF, and NSSM. During this Joint Task Force Exercise, oceanographers from Neptune Sciences, Inc. deployed a prototype wave buoys from Riseley Pier, SBE 26 Wave Tide Gauges at Onslow Beach, and weather stations. Observed data were compared and contrasted with numerical model output. This work was directly relevant to the Distributed Integrated Ocean Prediction System that has been documented at several of the International Workshops on Wave Hindcasting and Forecasting. Military observers of this exercise were from Assault Craft Units, the II Marine Expeditionary Force, and the Office of Naval Research. Observers from Marine Corps Base, Camp Lejeuene were presented with the idea of supporting Base environmental programs to include pre-deployment training of the Marine Expeditionary Units by utilizing Riseley Pier as the facility for a data acquisition system for wave buoys, water level gauges, and current meters.

52. Nichols, C. Reid, 2003. Coastal Awareness and Preparedness, *Sea Technology*, Arlington, VA: Compass Publications, Inc. Volume 44, No. 2, p 85.

A published essay describing the use of real-time environmental sensors to support security operations at critical facilities, seaports, etc. The points made in this article are relevant to supporting military training from combat swimmer instruction to amphibious landings at training beaches located at Camp Lejeune, Camp Pendleton, Camp Smith, etc. Real time data is also relevant to spinning up trajectory drift models to mitigate environmental terrorism (nuisance mines and marine spills). Measuring parameters such as boat wakes also provides current information to understand changes from expected background conditions.

53. Nichols, C. Reid and Andrew S. Lomax. Integrated Ocean Program: Analysis from Observed, Modeled, and Hindcast Data. NSI Technical Report to Naval Research Laboratory, Stennis Space Center, MS, December 1998.

This contractor report describes data collections that were used to assess the skill of the Distributed Integrated Ocean Prediction System. Various models were utilized to forecast waves and currents in zones important to maneuver and mine countermeasures, specifically offshore, shallow water, very shallow water, and surf zone. Their skill was assessed by Neptune Science oceanographers and Naval Research Laboratory scientists using data collected from the “Moored Littoral Wave Buoy,” Expendable Wave Tide Gauges, Davis Weather Station, and the SeaBird SBE 26 wave and tide guage. These data were also used in other publications and conference proceedings relevant to wave hindcasting and forecasting.

54. Nichols, C. Reid, David L. Porter, and Robert G. Williams, 2003. *Recent Advances and Issues in Oceanography*, Westport, Connecticut: Greenwood Publishing Group, 424 pp.

This general reference describes and evaluates research developments in oceanography. Topics include advances in measuring ocean phenomena from space, *in situ* instruments, and the development of fully integrated observing systems that allow investigators to take environmental "snapshots" of areas that must be monitored in order to protect property and save lives. This reference book may be obtained from the Nimitz Library (410-293-2420) at the US Naval Academy, the Maury library (228-688-4597) at Stennis Space Center, MS, the Ruth H. Hooker Research Library (202-767-2134) in Washington, D.C., and at the Library of the Marine Corps at Quantico, Va.

55. Nichols, C. Reid, David W. Tungett, and Richard A. Allard. Buoys Provide Real-Time Surf Data, November 1998 publication of United States Naval Institute’s *Proceedings* magazine.

This technical note documented the use of small, lightweight recording buoys by U.S. Navy beachmasters to provide timely and accurate information for controlling boat lanes and tracking real time changes in surf conditions. The wave buoys were used with the Navy Standard Surf Model to forecast a wide variety of surf zone parameters. The automated surf forecasts were compared to those completed by an observer on the beach. This deployment and data collection occurred during the NATO Exercise, RAPID RESPONSE/STRONG RESOLVE.

56. Nichols, C. Reid, Douglas Lamb, Timothy Donato, and X. -H. Yan, 2004. Oceanographic Information Collection and Data Availability for the Han River Estuary, NRL Memorandum Report, NRL/MR/7205—04-8837, Naval Research Laboratory, Washington, D.C.

This quickly written memorandum report described remote sensing approaches, existing data, and publications relevant to tidal flats found along the west coast of Korea. It was completed for Marine Corps Intelligence Activity as a literature search for a larger program that would involve characterizing estuarine coasts with macro-tidal ranges and extensive tidal flats.

57. Nichols, C. Reid, Doug Lamb, and Timothy Donato, 2005. Environmental Characterization in Support of the Detailed Assessment Plan for the Operational Assessment of the Expeditionary Fighting Vehicle, White Paper, Naval Research Laboratory, Washington, D.C.

An essay written for Marine Corps Operational Test and Evaluation Activity that suggested an initial set of instrument types and analysis techniques that could be incorporated into the operational assessment. Procedures to fill information gaps included recommendation to utilize directional wave buoys, weather stations, and to request the Naval Oceanographic Office's Fleet Survey Team to complete hydrographic surveys offshore of Camp Pendleton and Valdez, Alaska. The resulting expeditionary hydrographic surveys and environmental impact assessments can be obtained from MCOTEA (Attn: EFV TB) in Stafford, Virginia.

58. Nichols, C. Reid and Garth A. Jensen. South Florida Ocean Measuring Center: Observations to Improve Littoral Operations, in Susan Allersmeyer-Rosendale (Ed.), Geospatial Times, p. 3, Volume 3.2 - Spring 2001, Marine Corps Intelligence Activity, Quantico, VA.

An article published for geospatial information and services professionals which highlighted the use of real-time meteorological and oceanographic parameters such as winds and waves to assess features such as the waterline. Systems such as the South Florida Ocean Measuring Center (SFOMC) measure, analyze, archive, and disseminate coastal environment data for use by coastal engineers, coastal zone managers, scientists, and mariners.

This article also describes the push to install ocean observing systems around the United States. Amphibious craft tests and evaluations could be planned in areas where sensors are already located. For example, training areas in Camp Lejeune are covered by the Carolina Coastal Ocean Observing and Prediction System (http://www.carocoops.org) and the Southeast Atlantic Coastal Ocean Observing System (http://www.seacoos.org). Training areas at Camp Pendleton are covered by the Coastal Data Information Program (http://cdip.ucsd.edu/) and the San Diego Coastal Ocean Observing System (http://www.sdcoos.ucsd.edu/).

59. Nichols, C. Reid, Jack G. McDermid, Marshall D. Earle. Realistic Number-Crunching Gets Troops Ashore, February 1998 publication of United States Naval Institute's *Proceedings* magazine.

A technical note discussing the use of databases, wave buoys, and the Navy Standard Surf Model to support operations such as navigation in the coastal ocean and surf zone breaching. Work to run the surf model to support naval architects, engineers, and military planners was described in this article.

60. Nichols, C. Reid, John R. Schultz, and Shane M. Mayfield. Air and Sea Surface Temperature Analyses for The World's High Temperature Regions, NSI Report to NRL-SSC, January 1997, 216 pp.

This report describes a research study by Neptune Sciences, Inc. that involved quantifying atmospheric temperature data obtained from the Comprehensive Ocean Atmosphere Dataset and selected weather stations. The report was provided to the Direct Reporting Program Manager for Advanced Amphibious Assault to support analyses of engine compartment sizes and engine cooling requirements. Using actual air and sea surface temperatures from 24 years of ship observations, the investigators found that the Persian Gulf had the highest average air and water temperatures with mean values of 89.8 ˚F, and 89.9 ˚F, respectively. The most extreme air temperature value was 124.6 ˚F from the Persian Gulf. This report provides maps of the world's high temperature regions and air temperature histograms, probability tables, and descriptive statistics by month. This report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

61. Nichols, C. Reid and Leonard J. Pietrafesa, 1997. Oregon Inlet: Hydrodynamics, volumetric flux and implications for larval fish transport. Department of Energy technical report DOE/ER/61425-T3. 45 pp.

This technical report was submitted to the Department of Energy and highlighted the influence of synoptic scale weather on ebb and flood flows through Oregon Inlet on the Outer Banks of North Carolina. The report quantified transport of water through the inlet in response to wind-induced pressure heads. Measurements illustrated reduction of the tidal signal within 2.5 km of the coastal inlet. Water masses were also tracked through the inlet. This work is directly relevant to understanding non-tidal forces (hydraulic currents) and buoyancy fluxes that impact maneuver and the tacking of nuisance mines.

62. Nichols, C. Reid, Leonard J. Pietrafesa, Daniel Q. Egge. Camp Lejeune Integrated Observation Network, in Proceedings of the MTS/IEEE Oceans 2002 Annual Conference, Biloxi, Mississippi, 29-31October 2002, 6 pp.

The Camp Lejeune Integrated Observation Network (CLION) was intended to be a local observing network implemented by the Marine Corps Base (MCB) Camp Lejeune, Jacksonville, NC, to provide rapid assessments of ocean and atmospheric conditions for use in planning and conducting traditional training events, simulations, and amphibious exercises at the base. The Carolinas Coastal Ocean Observing and Prediction System (Caro-COOPS) was funded to install a water level station at Riseley Pier. The station was supposed to be built to NOAA standards and transmit water level data and winds in real-time to Caro-COOPS data centers. The actual name of the Marine Corps' portion of this capability was changed to Camp Lejeune Integrated Operations Network and was considered relevant to several Departments within the Base, e.g., Installation, Safety and Security as well as Training and Operations. Camp Lejeune helps fund a wave buoy located off of Onslow Bay that is operated by the National Data Buoy Center.

63. Nichols, C. Reid and Marshall D. Earle. Use of a Coupled Wave Buoy-Surf Model System to Support Combined Joint Task Force Exercise-96/Purple Star, NSI Field Report to Naval Research Laboratory, Stennis Space Center, May 1996, 22 pp.

This data report describes field work that was accomplished by Neptune Sciences, Inc. to support amphibious operations. This document also describes data assimilation and surf zone modeling procedures as well as all collected and derived data. Neptune Science Inc. participation in this military exercise was sponsored by the Naval Research Laboratory-Stennis Space Center. During this exercise, oceanographers from Neptune Sciences, Inc. deployed a prototype wave buoy from Riseley Pier at Camp Lejeune and used the buoy-derived wave spectra to run the Navy Standard Surf Model. Output was generated and compared to Surf Forecasts made by Navy SEALS. In addition, the wave buoy-surf model surf forecasts were used to support Assault Craft Unit Two from Little Creek, Virginia.

64. Nichols, C. Reid and Marshall D. Earle. Coast Types and Wave Statistics for Strategic Littoral Regions, NSI Report to Naval Research Laboratory, Stennis Space Center, April 1997.

This report by Neptune Sciences Inc. under sponsorship from Naval Research Laboratory was a spin off on Earle and Kennelly (1995). The purpose involved the development of descriptive coastal information, deep water wave probability tables, and Navy Standard Surf Model statistics for Direct Reporting Program Manager for Advanced Amphibious Assault (DRPM-AAA) action officers and engineers involved with war games. Littoral regions were associated with major ocean basins and marginal seas. The report provides a framework to characterize wave statistics, worldwide. Nine specific landing beaches were selected by action officers affiliated with Marine Corps Intelligence Activity and DRPM-AAA. Wave statistics based on ship observations were extracted from the Comprehensive Ocean Atmosphere Dataset and other climatological materials obtained from the National Climatic Data Center. The report identified deep and shallow water waves using the program RCPWAVE and surf using the Navy Standard Surf Model. This report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

65. Nichols, C. Reid, Marshall D. Earle, Jack G. McDermid, and Kim A. Kohler. Key Issues in Environmental Support to the Advanced Amphibious Assault Vehicle (AAAV), NSI Report to NRL-SSC, January 1998, 42 pp. plus appendices.

A recommended management structure and approach to address environmental factors for the EFV. The recommended program was designed to support tests, operational assessments, training, and safety. The report suggests the development of a coastal classification scheme that generalizes biological and physical forces that shape a coast as well as determining surrogate coasts that represent coastal zones found in foreign locations. Capabilities resident within the U.S. Navy METOC Support System and at the Naval Research Laboratory are linked to important environmental factors. Products that should be developed to support all field tests are discussed ranging from field and data quality assurance plans to data reports and final technical reports. General information on collection systems and products are described in figures and tables. Appendices include functional areas and measuring systems. A draft copy of this report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

66. Nichols, C. Reid and Marshall D. Earle. Use of a Coupled Moored Littoral Wave Buoy and Navy Standard Surf Model System to Support Strong Resolve-98, NSI Field Report to Naval Research Laboratory, Stennis Space Center, and Space and Naval Warfare Systems Command, April 1998.

This report describes a data assimilation and modeling effort that supported U.S. Navy and NATO ships operating in the Gulf of Cadiz. A weather station, wave buoys, and model were used to provide real-time weather across the landing beach during an amphibious assault near the Sierra Del Retin training area. Moored Littoral Wave Buoys were deployed at right and left flank beaches and a weather station was deployed nearby in Zaraha de Los Atunes. Wave buoy spectra, tide predictions, wind observations, and beach gradients were used as input the Navy Standard Surf Model. As a quality control check, surf forecasts were also made periodically by an Operations Specialist 2nd Class from Beach Master Unit Two. Environmental intelligence was passed to LCC MOUNT WHITNEY and HMS ROEBUCK approximately every four hours. This work was directly relevant to the Distributed Integrated Ocean Prediction System that has been documented at several of the International Workshops on Wave Hindcasting and Forecasting.

67. Nichols, C. Reid and Robert G. Williams. Variability of winds across the surf zone. in Proceedings of the MTS/IEEE Oceans Community Conference, Baltimore, MD, November 1998, 5 pp.

This professional paper was distilled from an earlier effort by Nichols et al. (1998). The study involved a comparison of winds at the beginning and end of the pier located at the Field Research Facility (FRF). The investigation was presented and published in conference proceedings. Results included the computation of long-term wind differences at the FRF, linear regression analysis of a two-day data set, duration of wind gusts, wait time between wind speeds, and cross correlation analysis.

68. Nichols, C. Reid and Robert G. Williams. *Encyclopedia of Marine Science*, New York: Facts on File, Inc. (in press)

This general reference describes approximately 600 marine science terms and will be published during 2008. It provides a simple word picture on terms that are common to oceanography, coastal engineering, ocean engineering, and marine technologies. This work can familiarize program managers to marine science, especially those wrestling with issues relevant to environmental factors. It suggests a starting point for obtaining deeper information on a particular topic as well as references and citations.

69. Nichols, C. Reid, Robert G. Williams, Theodore R. Mettlach, and Daniel A. Osiecki, 1998. Variability of Boundary Layer Winds across the Surf Zone, NSI Technical Report prepared for Coastal System Station, Panama Florida under contract from Naval Research Laboratory-Stennis Space Center, 52 pp., plus appendices.

Investigators from Neptune Sciences, Inc. completed an analysis of the variability of the horizontal wind across the surf zone form the water to a height of approximately 500 feet. Analysis used data sets acquired from the U.S. Army Corps of Engineers Field Research Facility in Duck, North Carolina. This work applied the logarithmic wind profile law and used linear regression to show that beach wind speed can be estimated from offshore wind speed with an accuracy of 2 knots. This work was important in being one of the first ever reports discussing winds over the surf zone. Appendices include logarithmic wind profile, flow over a barrier, 34-minute winds, scatter plots of u- and v-components, and linear regression curves. Nichols and Williams (1998) synthesized this material and presented findings at the annual Marine Technology Society conference. . The deliverable Neptune Sciences, Inc. technical report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

70. Nichols, C. Reid and Zdenka Willis. Buck Rogers Comes Alive in the 21ST Century, June 2001 publication of United States Naval Institute's *Proceedings* magazine.

An article describing the use of satellite imagery to characterize the maritime domain, especially in regions where sea ice forms. This work presents advances in satellite oceanography to characterize the environment to support operations such as icebreaking.

71. Osiecki, Daniel A., 1998. Determination of Offshore Bar Effects, NSI Technical Report prepared for Coastal System Station, Panama Florida under contract from Naval Research Laboratory-Stennis Space Center, 36 pp.

This technical report from Neptune Sciences, Inc. describes the effect of breaking and non-breaking waves on local bathymetry. The investigation used the Navy Standard Surf Model (NSSM) to assess the effects of longshore bars on surf zone parameters. Nearshore gradient numbers were applied after Earle and Kennelly (1995). The assessment was accomplished by comparing NSSM results for barred beach profiles with NSSM results for equilibrium beach profiles. An appendix provides plots of wave height and wave period, with and with out bars for selected nearshore gradient numbers. The deliverable Neptune Sciences, Inc. technical report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. During this timeframe, Ted Mettlach and Dan Osiecki also evaluated the sensitivity of the NSSM to bathymetric profiles derived from hydrographic surveys rather than those derived from the equilibrium beach profile. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

72. Puleo, Jack A., Gordon Farquharson, Stephen J. Frasier, K. Todd Holland, 2003. Comparison of optical and radar measurements of surf and swash zone velocity fields, Journal of Geophysical Research, 108(C3), 3100:45-1: 45-12.

Surf zone bore celerities and swash zone surface currents were measured on a shallow sloping, low-energy beach using two remote sensing methods that differ fundamentally in their imaging mechanisms. Microwave Doppler radar measures electromagnetic backscatter from small-scale ocean surface roughness while video-based particle image velocimetry (PIV) relies on image texture resulting from variations in light reflectivity from the ocean surface. Imagery from the two methods showed high correlation, in which regions of high radar backscatter corresponded to visibly identifiable waves and bores propagating across the surf zone. Correlation coefficients between radial velocity time series sampled using the two methods at multiple locations across the surf zone were typically greater than 0.5 for frequencies less than a noise cutoff of 0.25 Hz. Similarly, spectra were found to be coherent at the 95% level with a nearly zero phase shift between the two signals near the broad spectral peak between 0.02 and 0.25 Hz. However, some significant differences were evident. PIV was capable of estimating both cross-shore and alongshore surface velocities while the use of one microwave Doppler radar system restricted surface velocity estimates from that technique to line of sight (radial) only. PIV was found to be more capable of estimating swash zone (uprush and backwash) surface velocities as a smoother water surface in the swash zone adversely affected radar reflectivity. In contrast, microwave Doppler radar was found to be more capable of estimating the surface velocity between bores when insufficient image texture was recorded in the video imagery. Both techniques were capable of measuring surf zone bore celerities through comparison to a shallow water model and to independent celerity estimates extracted from the slope of individual bore trajectories. Typical normalized errors were roughly 25% for radar and 15% for PIV.

73. Schmidt, Anke, Volkmar R. Wismann, Roland Romeiser and Werner Alpers, 1995. Simultaneous measurements of the ocean wave–radar modulation transfer function at L, C, and X band from the research platform *Nordsee*, J. Geophysical Research **100,** 8815.

Radar backscatter measurements were performed from the German Forschungsplattform *Nordsee* (FPN) in the North Sea in order to determine the ocean wave–radar modulation transfer function (MTF), which relates the backscattered radar power to the long surface waves. The radar operated quasi-simultaneously at 1.0 GHz (L band), 5.3 GHz (C band), and 10.0 GHz (X band) at HH and VV polarization by using a single antenna. MTFs obtained at these radar frequencies and polarizations are compared. Our measurements of the dependence of the MTF on wind speed and long wave frequency are in agreement with earlier measurements. It is shown that the dependence of the coherence between the backscattered radar power and the long ocean wave height is a strongly decreasing function of radar frequency. This implies that a real aperture radar operating at a low radar frequency, e.g., at L band, is best suited for imaging ocean waves.

74. Schultz, John R. and C. Reid Nichols. Selected Navigable Inland Water bodies Meeting Advanced Amphibious Assault Vehicle Criteria, NSI Report to NRL-SSC, March 1997, 33 pp.

Investigators from Neptune Science Inc. under contract to the Naval Research Laboratory identified inland waterbodies meeting specific navigation requirements specified by the Direct Reporting Program Manager for Advanced Amphibious Assault. The study described riverine environments two-miles wide, at least two-miles long, 15 feet deep, and 150 m above sealevel. This inland waterbody criteria practically eliminated rivers from the search, but highlighted numerous lakes. Appendices included a listing of world rivers and lakes. A draft report with hand corrections is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

75. Schultz, John R., Marshall D. Earle, and Don Delbalzo. Stochastic Time-Series Simulation of Wave Parameters in Foreign Offshore Areas, NSI Report to NRL-SSC, December 1997, 28 pp.

Neptune Science Inc. investigators under contract to the Naval Research Laboratory provided a summary article on the development of statistically valid simulated wave time series. In addition, the Comprehensive Ocean-Atmosphere Database (COADS) and NDBC Buoy Station 46042 offshore of Monterey Bay, CA is used for the computation of frequency distribution functions, statistical hypothesis tests concerning means and standard deviations, and the computation of confidence intervals. Investigators attempted to simulate future wave parameters after techniques developed by Professor Leon E. Borgman. A skill score was developed based on the ratio of the mean square errors to determine the accuracy of simulations to the COADS data. This report is maintained by the Ocean Acoustics Branch of the Naval Research Laboratory located at the Stennis Space Center. The point of contact to access this report is Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

76. Schulz-Stellenfleth, Johannes and Susan Lehner, 2004. Measurement of 2-D Sea Surface Elevation Fields Using Complex Synthetic Aperture Radar Data, IEEE Transactions on Geoscience and Remote Sensing, 42(6):1149-1160.

A method is presented to derive two-dimensional sea surface elevation fields from complex synthetic aperture radar (SAR) data. Applied to spaceborne SAR data as acquired by European Remote Sensing 2 (ERS-2) or the Environmental Satellite (ENVISAT), the method allows the analysis of the structure of ocean wave fields, e.g., wave grouping or individual wave heights on a global scale. The technique, thus, provides wave parameters not obtained with common SAR wave retrieval schemes, which are designed to estimate the 2-D wave spectrum, i.e., second-order statistical moments of the wave field. Estimates of sea surface elevation fields are obtained based on the existing theory of SAR ocean wave imaging, i.e., the modulation of the SAR image intensity due real aperture radar and motion-related effects. A power series expansion is derived for SAR intensity images that enables the analysis of nonlinear effects as well as to derive a quasi-linear approximation of the SAR imaging model in the spatial domain. A statistical analysis is performed based on a global dataset of 2D wave spectra provided by the European Centre for Medium-Range Weather Forecast. Distributions are given for the relative error of the quasi-linear approximation in the spatial domain. It is shown that the error can be reduced by smoothing the SAR image in the azimuthal direction at the cost of lower resolution. Smoothed elevation fields are retrieved by the minimization of a cost function defined in the Fourier domain based on the quasi-linear approximation of the imaging process. A multilook technique is applied to infer the information on wave propagation directions, which is required because the SAR transfer function is non-Hermitian, i.e., the SAR image is not determined by the "frozen" sea surface, but wave motion has a significant impact. The method is applied to simulated SAR images as well as to data acquired by ERS-2. The errors of the retrieved wave field due to image noise, uncertainties in the SAR imaging model, and bandwidth limitations are analyzed. In particular, the fact that the estimated elevation field is smoothed due to the finite system resolution and smearing effects associated with wave motion is discussed. A statistical test is proposed to check the homogeneity of the SAR image. The method makes sure that atmospheric effects are not misinterpreted as being caused by ocean waves.

77. Schulz-Stellenfleth, Johannes and Susan Lehner, 2005. A Noise Model for Estimated Synthetic Aperture Radar Look Cross Spectra Acquired Over the Ocean, 43(7): 1443-1452.

It is well known that look cross spectra processed from synthetic aperture radar (SAR) contain valuable information on ocean waves. With the launch of the European satellite ENVISAT, SAR look cross spectra (SLCS) have become available on an operational basis. Activities therefore exist at different European weather centers to use the data for assimilation into numerical wave models. Furthermore there is scientific interest in SLCS, e.g., concerning the estimation of the phase speed of ocean waves. For the estimation of ocean wave parameters, it is important to have information about the accuracy of SLCS. In this paper, errors of estimated SLCS due to SAR image speckle, spectral estimation errors, and image pattern decorrelation associated with ocean wave motion are analyzed. A probability model is proposed for the estimated SLCS based on the respective cross-spectrum coherence. The model is used to calculate signal-to-noise ratios and confidence limits for the SLCS phase and magnitude, as well as the real and imaginary part. The coherence is factored into a component describing look decorrelation due to SAR image speckle and a second factor describing the effect of sea surface motion. It is shown that the ocean-wave-dependent decorrelation can be simulated using existing nonlinear integral transforms for the look variance spectrum and the SLCS. The decorrelation effect associated with speckle noise is related to SAR system parameters, e.g., the spatial SAR resolution. The probability model is used to investigate the optimal choice of look processing parameters like the look separation time. A statistical analysis based on a global dataset of a reprocessed dataset of European Remote Sensing 2 satellite SLCS is presented confirming the applicability of the probability model. The implications of the results for the retrieval of two-dimensional wave spectra from SLCS are summarized. Possible future applications of the model like, for example, the investigation of the turbulent air flow over waves, are discussed.

78. Soriano, G., M. Joelson, M. Saillard, 2006. Doppler Spectra from a Two-Dimensional Ocean Surface at L-Band. IEEE Transactions on Geoscience and Remote Sensing, 44(9):2430-2437.

An approximate time-harmonic three-dimensional electromagnetic boundary-integral method, the small-slope integral equation, is combined with a series expansion of the Creamer surface representation at second order with respect to the height, denoted by Creamer (2). The resulting model provides at low numerical cost simulations of the nonlinear ocean surface Doppler spectrum at L-band. As a result of approximations, the model is designed for a low-wind speed, typically up to 5 m/s. It is shown that applying directly a second-order model such as Creamer (2) to a semiempirical sea surface spectrum induces an unrealistic magnification of small-scale roughness that is involved in the scattering process at microwave frequencies. This paper thus proposes an undressed version of the Pierson–Moskowitz spectrum that corrects this artifact. Full-polarized Doppler simulations at L-band and 70incidence are presented. Effects of the surface nonlinearities are outlined, and the simulated Doppler spectra show correct variations with respect to wind speed and direction.

79. Sun, Jielun, Sean P. Burns, Douglas Vandemark, Mark A. Donelan, Larry J. Mahrt, Timothy L. Crawford, Thomas H. C. Herbers, Gennaro H. Crescenti, Jon R. French, 2005. Measurement of Directional Wave Spectra Using Aircraft Laser Altimeters. Journal of Atmospheric and Oceanic Technology, 22(7): 869-885.

A remote sensing method to measure directional oceanic surface waves by three laser altimeters on the NOAA LongEZ aircraft is investigated. To examine feasibility and sensitivity of the wavelet analysis method to various waves, aircraft motions, and aircraft flight directions relative to wave propagation directions, idealized surface waves are simulated from various idealized aircraft flights. In addition, the wavelet analysis method is also applied to two cases from field measurements, and the results are compared with traditional wave spectra from buoys. Since the wavelet analysis method relies on the “wave slopes” measured through phase differences between the time series of the laser distances between the aircraft and sea surface at spatially separated locations, the resolved directional wave number and wave propagation direction are not affected by aircraft motions if the resolved frequencies of the aircraft motion and the wave are not the same. However, the encounter wave frequency, which is directly resolved using the laser measurement from the moving aircraft, is affected by the Doppler shift due to aircraft motion relative to wave propagations. The wavelet analysis method could fail if the aircraft flies in the direction such that the aircraft speed along the wave propagation direction is the same as the wave phase speed (i.e., the aircraft flies along wave crests or troughs) or if two waves with different wavelengths and phase speed have the same encountered wavelength from the aircraft. In addition, the data noise due to laser measurement uncertainty or natural isotropic surface elevation perturbations can also affect the relative phase difference between the laser distance measurements, which in turn affects the accuracy of the resolved wave number and wave propagation direction. The smallest waves measured by the lasers depend on laser sampling rate and horizontal distances between the lasers (for the LongEZ this is 2 m). The resolved wave direction and wave number at the peak wave from the two field experiments compared well with on-site buoy observations. Overall, the study demonstrates that three spatially separated laser altimeters on moving platforms can be utilized to resolve two-dimensional wave spectra.

80. Ulak, Andy, 2006. Climatological Wind and Wave Measurments, Working Papers submitted to Naval Surface Warfare Center, 12 October 2006.

This unpublished technical memorandum by Mr. Andy Ulak (a U.S. Navy reserve METOC officer and a naval architect) to the Combatant Craft Department (see http://www.boats.dt.navy.mil/) discusses the need for environmental factors to support seakeeping prediction software. Both the JONSWAP and Bretschneider spectrum are advocated to approximate fully developed seas in the open ocean. Data from ship observations was downloaded from Global Atlas of Ocean Waves and displayed using a Geographic Information System. The data is presented as monthly statistics and as contour maps of significant wave height and dominant wave period. These working papers can be obtained from John M. Almeter (john.almeter@navy.mil) at Naval Surface Warfare Center-Carderock Division in Little Creek, Virginia.

It should be noted that there are various idealized spectra that are used to represent sea states by oceanographers, ocean engineers, and naval architects (See Michel, 1999). The most common is the Pierson and Moskowitz spectra (one parameter spectrum, significant wave height) first proposed in 1964 which assumes that if the wind blew steadily for a long time over a large area, the waves would come into equilibrium with the wind. This is the concept of a fully developed sea. The JONSWAP Spectrum was first described in 1973 based on measurements taken during Joint North Sea Wave Observation Project. This spectrum adapts the wave height and model period of the Bretschneider spectra for the limited fetch of the North Sea. Thus, advances from Pierson Moskowitz spectra relate to the finding that wave spectra are never fully developed and continue to develop through non-linear, wave-wave interactions even for very long times and distances. The 15th International Towing Tank Conference (ITTC) recommended the Bretschneider spectrum (two parameter spectrum, significant wave height and model frequency) for average sea conditions during 1978.

81. United States Naval Observatory, 2007. The Nautical Almanac for the Year 2008, Washington, D.C.: U.S. Naval Observatory.

The Nautical Almanac is an annual publication that provides astronomical data that is used for celestial navigation. This reference book includes the Greenwich hour angle and declination of the Sun, Moon, and navigational planets; the Greenwich hour angle of Aries; positions of the navigational stars; rise and set times of the Sun and Moon for a range of latitudes; and other data. The Nautical Almanac is the standard resource for marine celestial navigation for the U.S. Navy and also provides information on light levels such as the beginning of morning nautical twilight.

82. Violante-Carvalho, Nelson, 2005. On the retrieval of significant wave heights from spaceborne synthetic aperture radar (ERS-SAR) using the max-planck institute (MPI) algorithm. Anais da Academia Brasileira de Ciencias, 77(4):745-755.

Synthetic Aperture Radar (SAR) onboard satellites is the only source of directional wave spectra with continuous and global coverage. Millions of SAR Wave Mode (SWM) imagettes have been acquired since the launch in the early 1990's of the first European Remote Sensing Satellite ERS-1 and its successors ERS-2 and ENVISAT, which has opened up many possibilities specially for wave data assimilation purposes. The main aim of data assimilation is to improve the forecasting introducing available observations into the modeling procedures in order to minimize the differences between model estimates and measurements. However there are limitations in the retrieval of the directional spectrum from SAR images due to nonlinearities in the mapping mechanism. The Max-Planck Institut (MPI) scheme, the first proposed and most widely used algorithm to retrieve directional wave spectra from SAR images, is employed to compare significant wave heights retrieved from ERS-1 SAR against buoy measurements and against the WAM wave model. It is shown that for periods shorter than 12 seconds the WAM model performs better than the MPI, despite the fact that the model is used as first guess to the MPI method, that is the retrieval is deteriorating the first guess. For periods longer than 12 seconds, the part of the spectrum that is directly measured by SAR, the performance of the MPI scheme is at least as good as the WAM model.

83. Walsh, Edward J., Enzo A. Uliana and Benjamin S. Yaplee, 1978, Ocean wave heights measured by a high resolution pulse-limited radar altimeter, Boundary-Layer Meteorology 13, 263.

Radar measurements of wave height are compared with independent measurements made during the JONSWAP-2 experiment by Waverider and pitch-roll buoys, a shipborne wave recorder and a laser profilometer. The radar data were recorded by a Naval Research Laboratory (NRL) nanosecond-pulse X-band radar altimeter flown in a NASA C-54 aircraft at 3-km altitude under various wind and sea conditions. Averages of 800 pulses of the pulse-limited altimeter data were used to calculate maximum-likelihood estimates of significant wave height (SWH) and skewness of the sea-surface height distribution. The mean values of the radar-estimated SWH were in good agreement with the other measurements. The standard deviation of the values of the radar measurements was typically 10% of the average wave height. A two-dimensional computer simulation of the sea surface indicates that the major portion of the observed standard deviation is attributable to the relatively small sea-surface area illuminated by the radar (125 m × 900 m) rather than to instrumental error. Increasing the number of pulses averaged reduced the variance in the estimates without changing the means. The mean value of the skewness parameter was generally near zero but the standard deviation was typically 0.25. The estimate of SWH did not change when the skewness parameter was constrained to zero.

84. Williams, Robert G., Geoff W. French, and C. Reid Nichols, 1993. Nowcasting of currents in Tampa Bay using a physical oceanographic real-time system, in Proceedings, International Conference on HydroScience and Engineering, Volume 1, part B, Washington DC, pp. 1507-1512.

This article describes the application of statistics to provide current nowcasts to support ships turning into a harbor in Tampa Bay. A linear regression was completed from data collected at a key location under the Sunshine Skyway Bridge and at the Port Manatee channel junction. The current meter from Port Manatee was removed and deployed at another harbor entrance. The linear regression resulted in Port Manatee current nowcasts that supported the turning of commercial vessels by harbor pilots. This type of work can be accomplished at other locations given necessary and sufficient observations.

85. Wyatt, Lucy R., Jim J. Green, Klaus-Werner Gurgel, Jose C. Nieto Borge, Konstanze Reichert, Katrin Hessner, Heinz Günther, Wolfgang Rosenthal, Øyvind Saetra, Magnar Reistad, 2003. Validation and intercomparisons of wave measurements and models during the EuroROSE experiments. Coastal Engineering, 48:1-28.

The primary objective of the European Radar Ocean Sensing (EuroROSE) project involved monitoring and forecasting winds, waves, and currents, to support the ship traffic management in port approaches. This paper describes area covering ground-based remote-sensed wave and current data with high resolution numerical forecast models to provide now- and forecasts to marine operators. Two experiments to test and demonstrate the system took place: one on the coast of Norway, north of Bergen in March 2000 and the second on the north coast of Spain at Gijon in October/November 2000. Qualitative and quantitative intercomparisons of the wave measurements and wave model products from these experiments are presented. These include measurements using the WERA HF radar, the WaMoS X-band radar, a directional waverider and output from the WAM wave model. Comparisons are made of the full directional spectra and of various derived parameters. This is the first ever intercomparison between HF and X-band radar wave measuements and between either of these and WAM. It has provided a data set covering a much wider range of storm and swell conditions than had been available previously for radar wave measurement validation purposes and has clarified a number of limitations of the radars as well as providing a lot of very useful radar wave data for future model validation applications. The intercomparison has led to improvements in the data quality control procedures of both WaMoS and WERA. Limitations in the WAM model implementation are also discussed.

86. Zilman, Gregory and Lev Shemer, 1999. An Exact Analytic Representation of a Regular or Interferometric SAR Image of Ocean Swell, IEEE Transactions on Geoscience and Remote Sensing, 37(2): 1015-1022.

The problem of obtaining quantitative data on spatial ocean wave spectra from the images of the ocean surface by either regular SAR or along-track interferometric SAR (INSAR) is studied. The dominant mechanism which allows imaging of ocean waves by SAR/INSAR is the so-called velocity bunching. This mechanism is essentially nonlinear. The theoretical analysis of SAR/INSAR imagery of the ocean surface due to velocity bunching is performed, and nonlinear solutions of the SAR/INSAR images of monochromatic waves and of the spectra of these images are obtained. Analytic expressions are presented here which allow one to simulate accurately both SAR and INSAR images of waves with arbitrary lengths, heights and propagation directions. It is demonstrated that a monochromatic wave expands in the SAR/INSAR images into an infinite number of harmonics. In addition to the nonlinearity parameters of SAR which is related to the velocity bunching mechanism, it is shown that for complex INSAR, the degree of nonlinearity depends also on separation time between the two antennas. The results of the present study indicate that in addition to the prevailing practice to consider the phase component of the INSAR image, an analysis of the imaginary part of the complex INSAR map of the ocean surface may provide some supplementary information, beneficial, in particular, for rough sea.

IV. Electronic Resources

87. Bathymetry and Topography, National Geophysical Data Center, NESDIS, NOAA, Boulder, CO, Available online. URL: http://www.ngdc.noaa.gov/mgg/bathymetry/relief.html. Accessed on October 31, 2007.

A handy website fostering the ability to create shorelines and grids. This website provides access to survey data, bathymetric maps, digital elevation models, satellite-derived information. One well established product is the General Bathymetric Chart of the Oceans (GEBCO) which provides publicly-available bathymetric data sets for the world's oceans. One can also obtain gridded and contoured Digital Bathymetric Database survey data acquired from the U.S. Naval Oceanographic Office (See https://idbms.navo.navy.mil/dbdbv/dbvquery.html).

88. Coastal Data Information Program, Ocean Engineering Research Group, Scripps Institution of Oceanography. San Diego, CA. Available online. URL: http://cdip.ucsd.edu/. Accessed on October 31, 2007.

The Coastal Data Information Program (CDIP) is an extensive network for monitoring waves along the Pacific coasts. CDIP provides a database of publicly-accessible environmental data for use by coastal engineers and planners, scientists, mariners, and boaters. CDIP has been a leader in developing best practices for ocean observing systems, especially with and forefront of coastal monitoring, developing numerous innovations in instrumentation, system control and management, computer hardware and software, field equipment, and installation techniques. Such resources can directly support or augment environmental characterization efforts.

89. Coastal Engineering Manual, EM 1110-2-1100, US Army Corps of Engineers. Available online. URL: http://chl.erdc.usace.army.mil/CHL.aspx?p=s&a=Publications;8, Accessed on October 31, 2007.

A comprehensive manual that incorporates tools and procedures to plan, design, construct, and maintain coastal projects. The five volumes include the basic principles of coastal processes, methods for computing coastal planning and design parameters, and guidance on how to formulate and conduct studies in support of coastal flooding, shore protection, and navigation projects. This manual replaced the Shore Protection Manual.

90. Coastal Inlet Research Program, US Army Corps of Engineers. Available online. URL: http://cirp.wes.army.mil/cirp/cirp.html, Accessed on October 31, 2007.

The Coastal Inlets Research Program highlights research and developments that reduce the cost of dredging, promote navigation channel reliability, and understanding of the sediment-sharing interactions between inlets and adjacent beaches. Information and products from this website are directly relevant to the development of an environmental support plan for amphibious craft, patrol boats, and coastal ships.

91. Coupled Ocean/Atmosphere Mesoscale Prediction System, Marine Meteorology Division, Naval Research Laboratory, Available online. URL: http://www.nrlmry.navy.mil/coamps-web/web/home. Accessed on November 2, 2007.

The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®) has been developed by the Naval Research Laboratory. The atmospheric components of COAMPS® are used operationally by the U.S. Navy for short-term numerical weather prediction for various regions around the world.

92. Field Research Facility, U.S. Army Corps of Engineers, Duck, NC. Available online. URL: http://www.frf.usace.army.mil/. Accessed on October 31, 2007.

The Field Research Facility (FRF) is located on the Atlantic Ocean near the town of Duck, North Carolina. It is a model coastal observatory where instruments are deployed to measure waves, winds, tides, and currents. Central to the facility is a 560m (1840 ft) long pier and specialized vehicles. The FRF is a key location for basic and applied research on the coastal ocean, especially barrier island coast types. Products produced by the FRF include observations of environmental factors such as waves, tides, and currents, climatologies, bathymetry, and descriptions of experiments. From the FRF website, users may access Wave Information Studies, numerical hindcasts of wave climate for coastal waters in the United States.

93. Fleet Numerical Meteorology and Oceanography Detachment Asheville, NC, Fleet Numerical METOC Center. Available online. URL: https://navy.ncdc.noaa.gov/, Accessed on November 2, 2007.

Located at the National Climatic Data Center, METOC Officers and aerographer mates provide climatological products, data and services to support global operating forces of the Navy, Marine Corps and DoD. Major functions performed include (a) maintaining appropriate databases of surface and upper air meteorological observation data submitted by fleet and shore based Navy and Marine Corps units; (b) developing reviewing, and recommending updates to surface and upper air meteorological observation forms, technical manuals, observation procedures, and associated software programs; (c) planning, directing and supervising the development and routine updates of an interactive, digital based product suite of climatological references; (d) developing, submitting, and maintaining configuration management of designated atmospheric summarized climatological and observation databases for utilization in the Oceanographic and Atmospheric Master Library (OAML) and Naval Warfare Tactical Data Base (NWTDB); and (e) preparing tailored climatological summaries, tabulations and studies in response to requests from Navy and Marine Corps commands and in support of validated requirements tasked by higher authority.

94. Gulev, Sergey, Vika Grigorieva and Andreas Sterl, Global Atlas of the Ocean: based on VOS observations. Available online. URL: http://www.sail.msk.ru/atlas/index.htm. Accessed on November 2, 2007.

This Atlas was developed by oceanographers and scientists from the P.P.Shirshov Institute of Oceanology, Russian Academy of Science (Moscow), Southampton Oceanography Centre (Southampton) and Royal Netherlands Meteorological Institute (De Bilt) through funding from the European Union under INTAS grant 96-2089. The primary interest was the quantification of wave fields coming from different sources, i.e., *in situ* measurements of waves, voluntary observing ship sea state data, remotely sensed waves, and modeling output. This resource is particularly valuable since the investigators re-processed Comprehensive Ocean-Atmosphere Data Set (COADS) Releases 1a and 1b, which cover respectively the periods 1950-1979 and 1980-1997. Oceanographers from Neptune Sciences also re-processed COADS data owing to formatting problems and decoding values. For example, swell period codes were changed in 1968, but this change was not accepted simultaneously by all nations and owners of marine vessels.

95. International Comprehensive Ocean-Atmosphere Data Set (ICOADS). Available online. URL: http://icoads.noaa.gov/. Accessed on October 26, 2007.

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) is an archive of data that is stored in an ASCII format. Records are accessible through an online request interface that permits subsetting in space, time, and by parameter. The total period of record is currently 1784-May 2007 (Release 2.4). ICOADS data are made available as surface marine reports and monthly summary statistics. Marine reports contain individual observations of meteorological and oceanographic variables, such as sea surface and air temperatures, wind, pressure, humidity, and cloudiness. Summary statistics such as the mean and median are calculated for each of 22 observed and derived variables, using 2° latitude x 2° longitude boxes back to 1800 (and 1°x1° boxes since 1960). This database of observational records (surface marine reports from ships, buoys, and other platform types) has been used by numerous authors (Earle, 19xx; McDermid et al., 1997; Naval Research Laboratory, 1994 and 1995; and Nichols and Earle, 1997) to develop statistics within specific regions such as Marsden squares. The Marsden squares, which are grid cells of 10° latitude by 10° longitude between 80°N and 70°S latitudes, provide a convenient location to pull data such as wave heights, wave periods, and wave directions.

96. Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), Available online. URL: http://shoals.sam.usace.army.mil/. Accessed on October 31, 2007.

The Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) mission is to perform operations, research, and development in airborne lidar bathymetry and complementary technologies to support the coastal mapping and charting requirements of the US Army Corps of Engineers (USACE), the US Naval Meteorology and Oceanography Command, and the National Oceanic and Atmospheric Administration (NOAA). JALBTCX staff includes engineers, scientists, hydrographers, and technicians from the USACE Mobile District, the Naval Oceanographic Office (NAVOCEANO), the USACE Engineer Research and Development Center (ERDC), and NOAA National Geodetic Survey. These personnel plan and execute survey operations using the Compact Hydrographic Airborne Rapid Total Survey (CHARTS)

system and industry-based coastal mapping and charting systems. CHARTS includes a lidar instrument and a hyperspectral imager.

97. Large Marine Ecosystems of the World, Large Marine Ecosystem Program Narragansett Laboratory, NOAA-NMFS, Narragansett, RI, Available online. URL: http://woodsmoke.edc.uri.edu/Portal/, Accessed on October 31, 2007.

Large Marine Ecosystems are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major current systems. They are relatively large regions on the order of 200,000 km^2 or greater, characterized by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations. On a global scale, 64 LMEs produce 95 percent of the world's annual marine fishery biomass yields. Within their waters, most of the global ocean pollution, overexploitation, and coastal habitat alteration occur. For 33 of the 64 LMES, studies have been conducted of the principal driving forces affecting changes in biomass yields. They have been peer- reviewed and published in ten volumes (http://www.lme.noaa.gov). Based on lessons learned from the LME case studies, a five module strategy has been developed to provide science-based information for the monitoring, assessment, and management of LMES. The modules are focused on LME: (1) productivity, (2) fish and fisheries, (3) pollution and health, (4) socioeconomics, and (5) governance.

98. Long Term Ecological Research (LTER) Network, Available online. URL: http://www.lternet.edu/. Accessed on October 31, 2007.

The Long-Term Ecological Research (LTER) Program was founded by the National Science Foundation to support research on ecological phenomena occurring over long time periods and across a wide range of geographical scales. The LTER Program’s focus on integrated, multi-scientist investigations at every site leads to major syntheses and advances in the theoretical understanding of how ecosystems function. The LTER network comprises 26 field sites located primarily in the USA, with a geographic span from the poles to the tropics. The sites represent most of the Earth’s major ecosystems and include deserts, grasslands, forests, tundra, urban areas, agricultural systems, freshwater lakes, coastal estuaries and salt marshes, coral reefs and coastal ocean zones. Sites share a common research agenda in five areas, which allows for comparisons to be made across the network and beyond. The five areas are (1) pattern and control of plant production, (2) spatial and temporal distributions of representative populations of plants, animals, and microbes, (3) distribution and dynamics of organic matter in surface soils, water, or sediments, (4) patterns of inputs and movements of inorganic nutrients and chemicals through the ecosystems, and (5) patterns, frequencies and effects of disturbances such as hurricanes, landuse changes or forest harvesting.

99. Marine and Earth Sciences Dataservices, Institute for Science Networking Oldenburg GmbH, Germany, Available online. URL: http://www.marenet.de/MareNet/maredata.html#databases, Accessed on October 31, 2007.

This site provides information on worldwide distributed oceanographic data collections by listing links to related information sources.

100. MICRODEM, Oceanography Department, U.S. Naval Academy, Annapolis, Maryland, Available online. URL: http://www.usna.edu/Users/oceano/pguth/website/microdem.htm. Accessed on October 28, 2007.

MICRODEM is a microcomputer mapping program written by Professor Peter Guth. It requires a 32 bit version of Windows (NT/2000/XP or 95/98/ME) and supports the display and merging of digital elevation models, satellite imagery, scanned maps, vector map data, and GIS databases. Sources of input data are maps from the US Geological Survey, imagery from the National Geospatial-Intelligence Agency, and records from the National Ocean Service.

101. National Data Buoy Center (NDBC), National Weather Service, National Oceanic and Atmospheric Administration, Stennis Space Center, MS. Available online. URL: http://www.ndbc.noaa.gov/. Accessed on October 31, 2007.

The National Weather Service's NDBC website contains real-time and historic meteorological and oceanographic data from moored buoys and Coastal-Marine Automated Network (C-MAN) Stations.

102. NRCS Soils Website, Natural Resources Conservation Service, United States Department of Agriculture, Washington, D.C., Available online. URL: http://soils.usda.gov/. Accessed on October 28, 2007.

A repository for information on soils, soil taxonomy, and geographically associated soils. Databases include distribution and extent, range in characteristics, type location, drainage and permeability, and use and management for various types of soils. This site provides links to global soil resources. The NRCS Soils Website is a useful reference for trafficability studies that support the maneuver of amphibious craft such as the Joint Maritime Assault Connector and the use of resources such as mobility matting (MOMAT).

103. NOAA, Tide and Current Glossary, 2000. Silver Spring, MD: National Ocean Service, National Oceanic and Atmospheric Administration, Department of Commerce. Available online. URL: tidesandcurrents.noaa.gov/publications/glossary2.pdf. Accessed on October 26, 2007.

A detailed glossary defining terms associated with the collection, analysis, processing, and publication of data which is used for tide and current predictions. It is important that descriptive terms meaningful to Sailors and Marines by used to describe those environmental factors that impact safety and operations of amphibious craft, patrol boats, and coastal ships.

104. OceanColor Home, Goddard Space Flight Center, NASA, Greenbelt, Maryland. Available online. URL: http://oceancolor.gsfc.nasa.gov/. Accessed on October 28, 2007.

This website provides information on ocean color satellites such as MODIS (or Moderate Resolution Imaging Spectroradiometer) and SeaWiFS (or Sea-viewing Wide Field-of-view **S**ensor) as well as the associated data analysis systems available for the processing, display, analysis, and quality control of ocean color data. Imagery may be retrieved using a browseable web interface or through FTP. Various links provide users with access to instructions and data organized by satellite. These satellites are useful in detecting sea surface temperatures and the amount of phytoplankton in the water, which can be meaningful for many land and coastal ocean classification applications. Scales would be on the order of kilometers.

105. Tortell, Philip and Larry Awoska, 1996. Oceanographic Survey Techniques and Living Resources Assessment Methods, Intergovernmental Oceanographic Commission Manuals and Guides No. 32, Paris, France: United Nations Educational, Scientific and Cultural Organization. Available online. URL: http://ioc.unesco.org/iocweb/iocpub/iocpdf/m032.pdf. Accessed on October 31, 2007.

A general document describing date elements and parameters that should be measured to support environmental impact assessments and coastal zone management. This work is applicable to understanding environmental factors impacting amphibious craft.

106. United Kingdom Hydrographic Office, Admiralty EasyTide, Available online: URL: http://easytide.ukho.gov.uk/EasyTide/EasyTide/index.aspx. Accessed on October 26, 2007.

Admiralty EasyTide and TotalTide are tide and tidal current prediction programs for over 7,000 tide stations and 3,000 tidal current stations, worldwide. Admiralty TotalTide is a “for official use only” tide and tidal prediction CDROM version of EasyTide that may be obtained through coordination with the National Geospatial-Intelligence Agency. A TotalTide license is for one year, which benefits from the UK Hydrographic Office’s annual updating of their worldwide harmonic constant database. Some tide and current terms in this software are slightly different than those used by the National Oceanic and Atmospheric Administration. Tide and current terms are defined in NOAA’s Tide and Current Glossary.

107. United Nations Atlas of the Oceans, Available online. URL: http://www.oceansatlas.org/index.jsp. Accessed on October 31, 2007.

A continuously updated database that contains information relevant to the sustainable development of the oceans and the state of ocean resources. The database provides descriptive information on the history, physical characteristics, biology, and ecology of the oceans, including maps and statistical information.

108. Wave Buoy Survey, The Johns Hopkins University Applied Physics Laboratory, Laurel, MD. Available online. URL: http://fermi.jhuapl.edu/usmc/. Accessed on October 28, 2007.

A web site providing basic information on the ease of deployment and operation of wave buoys manufactured by several different vendors. The Wave Buoy Survey was developed by Dr. David L. Porter prior to the start of the operational assessment of the Expeditionary Fighting Vehicle. It was designed so that program managers would have a location to search having objective information relevant to the utility of wave buoys to support planing craft, hovercraft, and sea state limited operations such as surf zone breaching. Dr. Porter is key oceanographer affiliated with the Office of Naval Research’s Littoral Warfare Advanced Demonstration Program.

109. Wave Information Studies, Coastal and Hydraulics Laboratory, U.S. Army Corps of Engineers. Available online. URL: http://frf.usace.army.mil/cgi-bin/wis/atl/atl_main.html. Accessed on October 31, 2007.

A Wave Information Study (WIS) produces hindcast data generated from numerical models such as WISWAVE and WAM that are driven by climatological wind fields overlaid on grids containing estimated bathymetries. The major parameters are significant sea height, dominant sea period, sea direction, sea swell height, sea swell period, and sea swell direction. Regions of primary interest to the U.S. Army Corps of Engineers are adjacent to the United States' Atlantic, Gulf of Mexico, and the Pacific Coasts. Publications and digital data sets of the actual analysis of the wave information study resident at the U.S. Corps of Engineers are available to outside users via the WIS website or by contacting the National Climatic Data Center Customer Services (see URL: http://www.ncdc.noaa.gov/oa/ncdc.html, e-mail: ncdc.info@noaa.gov or tel: (828) 271-4800).

110. World Ocean Database 2005, National Oceanographic Data Center, National Oceanic and Atmospheric Administration, Available online. URL: http://www.nodc.noaa.gov/OC5/WOD05/pr_wod05.html, Accessed on October 28, 2007.

The World Ocean Database 2005 is an archive of data from Conductivity-Temperature-Depth (CTD) casts, water bottle and bucket collections, plankton net tows, and most recently, data collected from instrumented autonomous underwater vehicles and gliders. Observations mostly relate to the water column and include variables such as temperature, salinity, oxygen (dissolved oxygen, apparent oxygen utilization, and percent oxygen saturation), dissolved inorganic nutrients (phosphate, nitrate, and silicate), chlorophyll at standard depth levels, and plankton biomass sampled from 0 - 200 meters. The database has codes for wave direction, wave height, sea state, wind force, wind direction, weather condition, etc. Some of the data in this archive can be used to complement satellite imagery exploitation and may be useful in assessing heat flow in the ocean, especially as it relates to engine cooling. The entire database is available on DVD. The Naval Oceanographic Office also provides the Generalized Digital Environmental Model or GDEM, a global climatology of temperature, salinity, temperature standard deviation, and salinity standard deviation (see URL: https://idbms.navo.navy.mil/gdemv/gdemv.html).

V. Summary

This annotated bibliography lists numerous citations to books, articles, documents, and databases highlighting environmental conditions that impact the safety and performance of amphibious craft, patrol boats, and ships designed for coastal operations. Some of the described work was originally planned and delivered to support design of the Expeditionary Fighting Vehicle or the use of line charges deployed from Landing Craft Air Cushion to clear boat lanes of mines and obstacles. There are many other references in the literature relevant to the characterization of environmental conditions such as ambient air temperature, sea conditions (wave height, wave period, wave direction, tidal regime, and currents), wind conditions (direction, speed, and gusts), terrain (beach gradients and obstacles), and surf zone parameters (breaker type, surf zone width, longshore currents). The following table is provided to link the listed references to important environmental factors.

Environmental Factors and Cited Works. References found in this annotated bibliography are categorized by the general type of study and environmental factors. Works may be categorized in more than one cell.

Environmental Factors	Print Resource				Electronic Resource			
	Databases	Remote Sensing	*In Situ* Sensors	Models	Databases	Remote Sensing	*In Situ* Sensors	Models
Air Temperature	34, 44, 45, 47, 60, 66		48, 51, 53, 57, 58, 61, 63, 66		88, 92, 93, 95, 101	93	88, 92, 93, 95, 98	
Bathymetry	10, 44, 45, 47, 66	1, 4, 5, 6, 22, 30, 32, 33, 42	51, 53, 57	14, 37, 59, 63	87, 90, 92, 93, 97, 98, 99, 105, 110	96, 107	93, 110	
Beach Gradients	10, 44, 45, 47, 66	5, 6, 9, 13, 22, 72	23, 51, 53, 55, 57, 60, 63	14, 37, 38, 39, 40, 55, 59, 71	87, 90, 92, 93, 98	96		90
Currents	10, 44, 45, 74	1, 7, 8, 12, 22, 43, 72, 85	11, 16, 48, 49, 53, 57, 58, 61, 84	3, 15, 38, 39, 46, 47, 55, 71, 84, 85	88, 92, 93, 95, 98, 105, 110	93	88, 92, 93, 95, 110	93, 107
Relative Humidity	34, 44, 45, 47		47, 50, 52, 56, 57, 65		93, 101		88, 92, 93	
Sea Surface Features	40, 44, 45, 47, 75, 80	2, 12, 17, 31, 42, 70, 72, 73, 76, 77, 80, 82, 85, 86	11, 23, 40, 58, 63	40, 85	88, 92, 93, 94, 95, 98, 99, 101, 105, 110	88, 92, 93, 96, 104	88, 92, 93, 95, 101, 108, 110	88, 92, 93, 107
Surf	10, 13, 15, 50, 59	12, 21, 22, 31, 72	23, 51, 53, 55, 57, 59, 60	13, 14, 15, 31, 36, 37, 39, 44, 45, 50, 55, 59, 63, 64, 65, 71	92	88, 92, 93, 96	88, 92, 93	88, 92, 93
Surface Gravity Waves	36, 40, 43, 45, 47, 50, 64, 75, 80	9, 12, 13, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 31, 41, 73, 76, 77, 78, 79,	11, 23, 40, 51, 53, 55, 57, 58, 59, 60, 63, 66, 83	3, 9, 14, 15, 18, 19, 36, 37, 38, 39, 40, 44, 45, 50, 55, 59, 64, 66, 75, 85	88, 92, 93, 94, 95, 101, 109, 110	88, 92, 93, 96	88, 92, 93, 108, 110	88, 92, 93, 109

		82, 83, 85, 86						
Terrain	10, 44, 45, 74	6, 7, 22, 26			93	93, 96, 90, 107		
Tidal Currents	10, 44, 45		16, 48, 49, 57, 60, 61	47	88, 92, 93		88, 92, 93	88, 92, 93, 106
Water Levels	10, 44, 45, 74	7, 8	11, 48, 51, 53, 57, 58, 61	3, 59	7, 8, 92, 93, 110	93, 96	88, 92, 93, 98, 110	88, 92, 93, 106
Waterlines		7, 8				7, 8		
Water Temperature	10, 44, 45, 47, 60		48, 51, 53, 57, 58, 61, 63, 66		88, 92, 93, 95, 101, 105, 110	88, 92, 93, 104	88, 92, 93, 95, 98, 110	88, 92
Winds	34, 40, 43, 45, 47, 64, 66, 67, 69	24, 28, 42	23, 40, 48, 49, 51, 53, 57, 58, 61, 63, 66, 67, 69	3, 34, 39, 40, 59	88, 92, 93, 95, 101, 105, 107	88, 93	88, 92, 93, 98	88, 91, 93
References 35, 43, 52, 54, 56, 62, 65, 68, 70, 89, 100, 105, and 108 relate to capabilities and were not considered in this table. In many instances these references could be associated with each cell. Reference 81, 99, 102, and 103 are useful in understanding other features such as tides, currents, visibility, and trafficability.								

VI. APPLICATIONS GUIDANCE

Many of the cited references should be scanned and archived in a DVD as a compendium of references relevant to environmental support to amphibious craft, patrol boats, and coastal ships. This memorandum report would also be incorporated into the DVD with links to appropriate Portable Document Format files or websites. Given the location of many of the cited contractor reports, this task might be accomplished at the Stennis Space Center using the resources of the Maury Library, and under supervision of Mr. Jack McDermid at 228-688-5254 or Jack.McDermid@nrlssc.navy.mil.

This memorandum report allows scientists and engineers to use the cited references as a starting point to develop a characterization scheme to assess environmental factors that influence operations of a wide variety of amphibious craft, boats, and ships that all navigate estuaries and the coastal ocean. These background documents provide the basis for developing documents such as a Safe Engineering and Operations Manual for Joint Maritime Assault Connector (JMAC) as well as revised technical reports such as “Key Issues in Environmental Support to the Advanced Amphibious Assault Vehicle (AAAV)” by Nichols et al. (1998). This annotated bibliography is a starting point to build a complete environmental support plan for the Expeditionary Fighting Vehicle (EFV), JMAC, and the Transition Craft (T-Craft). Basic and applied researchers from the Naval Research Laboratory and the U.S. Army Corps of Engineers should collaborate to validate an environmental support planning document.

Plan and execute a workshop that discusses environmental factors that support the safe engineering and operations of amphibious craft, patrol boats, and coastal ships. The workshop could review and edit a draft environmental support plan that describes authoritative approaches to environmental characterization. Techniques would include basic online searches for data and descriptive statistics, remote sensing and imagery analysis, numerical modeling, *in situ* data collection activities, and where appropriate, real-time observations of environmental factors. Working groups would be planned to focus on particular environmental factors and analysis techniques. This workshop is presently being planned from 0800 til 1630 on 16 January 2007 at the Naval Surface Warfare Center Conference Center in Carderock, Maryland. During this workshop, additions and deletions to the annotated bibliography should be suggested prior to making a DVD. Environmental factors might be extracted from DoD's Integrated Weather Effects Decision Aid (IWEDA) to ensure this tool includes amphibious vehicle requirements.

Develop a hierarchical coastal classification system for the remote sensing and mapping community. Use principles published by Rusak & Company in *Geological Oceanography* by Francis Shepard in 1977 (see McDermid et al., 1997) as a starting point to build coverages highlighting coast types such as barrier island, coral atoll, cuspate foreland, deltas, drowned river, drumlins, fault, fiords, mangrove, polar, rivers, urban, and volcanic. Since coast types are formed based on prevailing biological and physical factors, determine estimates or generalizations for the factors that impact maneuver based on distinct coast types. As part of the Hydrodynamic Agents in the Littoral Environment (See Bachmann et al. 2007), the Remote Sensing Division of the Naval Research Laboratory is analyzing features for several different coast types. This information that includes time series of parameters and features extracted from imagery is being stored in a geodatabase.

Pull commercial imagery from databases such as the Commercial Satellite Imagery Library to develop geodatabases for strategic areas. Use ArcGIS to showcase important coastal features such as waterlines and beach extent. Such a project is the 21st Century update to the Bird and Schwartz (1985) work entitled, *The World's Coastline*. It can also be the basis to complete the document, "Coast Types and Wave Statistics for Strategic Littoral Regions" by Nichols and Earle (1997). This effort would rely on archives such as the International Comprehensive Ocean Atmospheric Database (ICOADS) and would be enhanced by remote sensing and numerical modeling. The final result is the synthesis of information from databases, imagery stacks, and model output. As part of the Hydrodynamic Agents in the Littoral Environment (See Bachmann et al. 2007), the Remote Sensing Division of the Naval Research Laboratory is building geodatabases for several different coast types. These should be made available to acquisition and intelligence personnel via NIPRNET and SIPRNET.

Pull necessary and sufficient data relevant to environmental factors from the various global databases and ocean observatories. Compare and contrast archives of observations with modeled data and fill information gaps as appropriate. Quality control the extracted information and build statistical tables that support naval architects, marine engineers, ocean engineers, scientists, and managers focused on the design and testing of amphibious craft. During all tests and evaluations collect, analyze, describe, and archive data for environmental factors. This information also benefits the modeling and simulation community by providing information to assess the fidelity of simulations. Being able to access authoritative environmental information should be paramount to the planning and implementation of operational trainers.

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